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ENVIRONMENTAL EDUCATION COURSES WITH EMPHASIS ON RHODOPES COMPLEX

UNDER THE FRAMEWORK OF THE EDUCATIONAL COOPERATION
ON ENVIRONMENTAL ISSUES OF DRAMA-SMOLYAN AREAS
THROUGH THE USE OF INNOVATIVE TECHNOLOGIES

ОСНОВНИ ПРОБЛЕМИ, СВЪРЗАНИ С ОПАЗВАНЕ НА ПРИРОДНАТА СРЕДА В РАЙОНА НА РОДОПИТЕ

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Επιμέλεια έκδοσης: Δημήτριος Εμμανουλούδης
Αγγλική μετάφραση: Νανά Χατζίκου
Βουλγαρική μετάφραση: Σταματία Αργυρούδη
Επιμέλεια ύλης: Διαλεχτή Τζανερίκου
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Text's arrangement: Dialechti Tzanerikou
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Technological Educational Institute of Kavala, Drama Annex
Department of Forestry and Natural Environment Management
1st km Drama - Microhori, Drama 66100, Greece.
Tel.: +30 25210 60402, +30 25210 60419

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DEVELOPMENT OF JOINT
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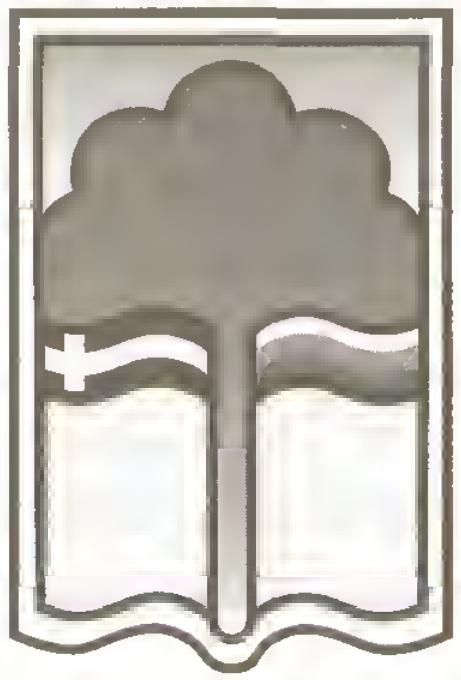

INTERREG IIIA/PHARE CBC GREECE - BULGARIA

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DRAMA 2007

Συγγραφείς του τόμου

Ν. Αβτζής, *καθηγητής*

Ν. Ελευθεριάδης, *καθηγητής*

Δ. Εμμανουλούδης, *Αν. καθηγητής*

Μ. Λαζαρίδου, *καθηγήτρια*

Θ. Μέρου, *Επ. καθηγήτρια*

Ι. Μητσόπουλος, Δρ - *Ερευνητής*

Ι. Τάκος, *καθηγητής*

Contributing Authors

N. Avtzis, *Professor*

N. Eleftheriadis, *Professor*

D. Emmanouloudis, *Assoc. Professor*

Th. Merou, *Assist. Professor*

I. Mitsopoulos, *PhD Researcher*

I. Takos, *Professor*

INTRODUCTORY NOTE BY THE PROJECT SCIENTIFIC MANAGER

Drama, April 2007

This book has been realized by a group of professors of the Forestry and Natural Environment Management Faculty of the Technological Educational Institute (TEI) of Kavala, Drama branch, and professors of the Smolyan Pedagogy Department of Plovdiv University in Bulgaria.

It consists of a number of environment related courses with particular stress on Rodopi region in both sides of the two countries borders. The courses include a number of basic concepts in specific thematic units and cover all the subjects pertaining to the study and knowledge of the natural environment, as a whole.

This book consist a member of a more set of educational tools (CDs, posters etc.) that are funded and produced by INTERREG IIIA / PHARE CBC GREECE-BULGARIA within the framework of the project έργου "DEVELOPMENT OF JOINT EDUCATIONAL ACTIVITIES IN NATURAL ENVIRONMENT OF THE AREAS DRAMA – SMOLYAN BY USING NEW TECHNOLOGIES".

As a project coordinator, I wish to thank all my Greek and Bulgarian colleagues for their precious contribution.

Particular thanks also should be addressed to the two translators, Mrs. Athina Chatzikou and Stamatia Argyroudi for their especially careful work as well as to the Project's Secretary, Mrs. Dialechti Tzanerikou, for the text's arrangements.

I am confident that such efforts of common educational cooperation between the two countries should be carried on in the future especially since Bulgaria has become a full member of the European Union.

D. Emmanouloudis

Associate Professor of TEIK

FOREST ECOLOGY

INTRODUCTION

Forest biosociety

Nature's basic functional unit, the **ecosystem**, consists of the biotope (or geosociety) and biosociety.

The **biotope** is characterized by the climate and the soil of an area, that is the sum of the abiotic factors (physical and chemical) affecting a specific area (solar radiation, wind, temperature, moisture, soil nutrients etc.).

The **biosociety** is the sum of the biotic elements e.g. plants (phytosociety), animals (animal society) and microorganisms. There is an constant interaction between the biotope and biosociety allowing the constant transfer of energy.

If a phytosociety is dominated by higher plant species (trees and shrubs), it is called a **forest ecosystem** or a **forest biogeosociety**. A forest is one of the most complex natural ecosystems.

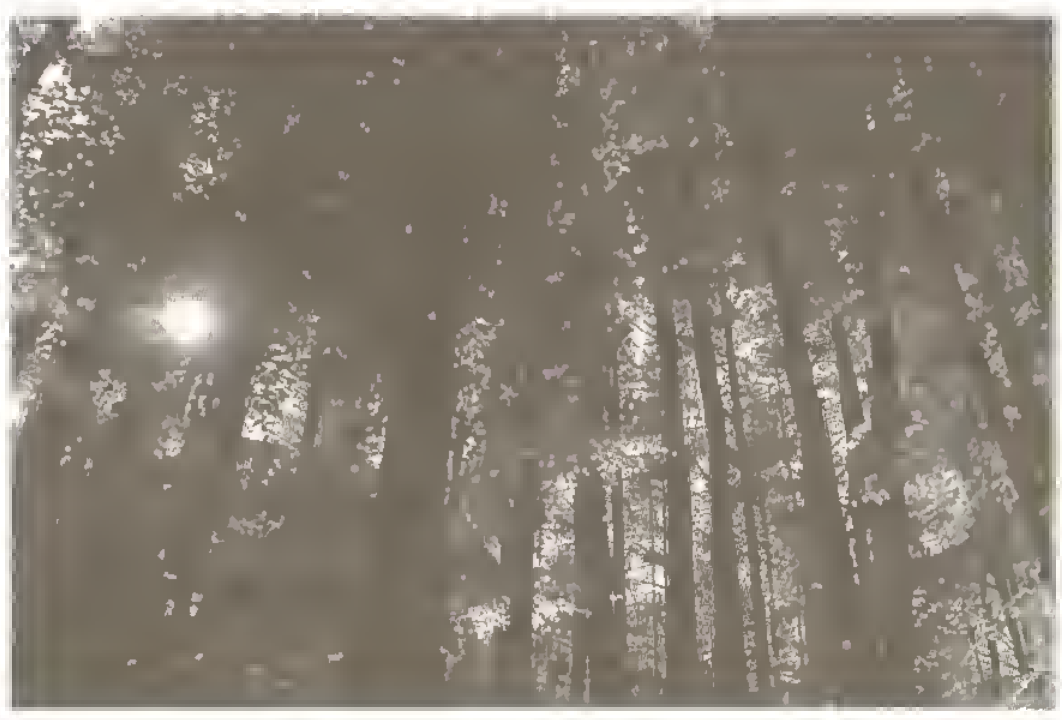
The forest concept

According to Dafis (1986) "a **forest** is a place where trees and shrubs coexist on a large surface in close social relationship and are close enough with eachother to form a special environment – the forest environment – and also, where, together with other plant and animal species, they form a special biosociety called **forest biosociety**". If the biotope is also taken into account, it is called **forest biogeosociety** or **forest ecosystem**.

Structure and operation of the forest ecosystem

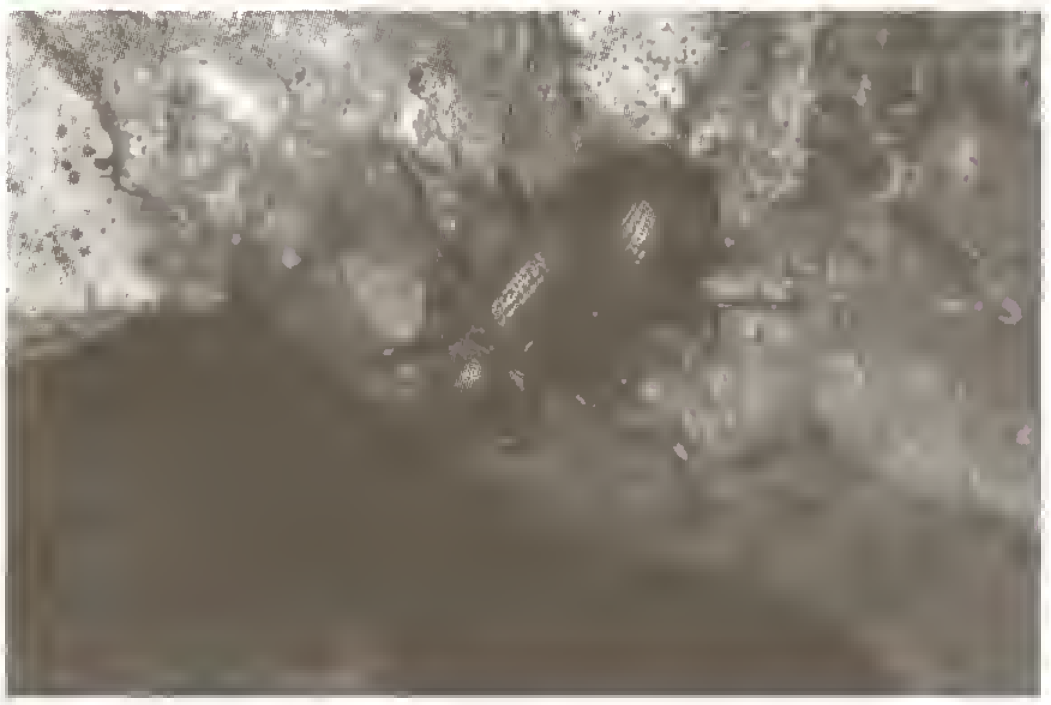
The forest ecosystems receive the raw material they need from the abiotic factors (solar radiation, CO_2, H_2O and inorganic substances).

Solar radiation is the main source of energy that is trapped by the plants through the photosynthesis process and is turned into energy-rich organic compounds.



Plants are the only organisms that can turn solar energy into chemical compounds and are therefore called **ecosystem producers.**

Through the organic compounds produced by the photosynthesis, the H_2O and the energy-poor inorganic substances that are uptaken by the soil through the root system, plants form the biochemical substanc-



es they need to develop and metabolize, and are, therefore, called **autotrophic organisms (self-feeders).**

The plant or plant products produced by the plants serve as a food for parasitic and herbivore plants (**primary consumers**).

This category includes the forest mammals (deer, rabbits, mice, squirrels) that feed on seeds, fruits, leaves, roots etc., the birds that feed on seeds and fruits and the folivorous insects. It also includes blastophagi – xylophagi insects and other pests that feed on leaves, fruits and wood.

The **secondary consumers** are the carnivore animals that feed on herbivore animals. By doing so, they regulate the population of the herbivores contributing in striking the balance between plants and herbivores.

The secondary consumers serve as food to bigger carnivore animals, the so-called third trophic level consumers or **tertiary consumers**.

Large quantities of organic compounds (leaf litter, animal excretions, dead and decaying material, dead animals) are accumulated on the ground and serve as food to another category of organisms, **the saprophages** (earthworms, arthropods etc) and ***decomposers*** (*bacteria and fungi*). The decomposers split the young organic matter converting it into anorganic substances that can be easily eaten by plants. In this way, decomposers start the cycle all over again.

The consumers and decomposers are called **heterotroph organisms** because they cannot produce organic substances and depend entirely on the producers.

Forest vertical stratification

Forest ecosystems are organized in layers allowing biosociety to make the best use

of the environmental resources. The forests consist of the following layers:

I. Canopy layer
II. Understory layer
III. Shrub layer
IV. Herb/fern layer
V. Meadow grass level
VI. Floor layer

Biosociety balance of the forest ecosystem

The salient characteristic of the forest ecosystems are the numerous, evolving interactions both between the biotic and abiotic factors of the ecosystem and between the members of each community.

A forest is not an "organism" in static balance but a community of members that are not organically related but have a dynamic balance. If a factor is altered, chain reactions occur to constant changes in the ecosystem until a new balance is established.

The interactions between the members of a biosociety are expressed in terms of **competition** and **interdependence** (mutual help).

There is a strong competition among the forest trees for more space, light, water and nutrients. The smaller the distance between the trees, the more their ecological requirements are alike and the stronger the competition among them.

Apart from the strong competition, there is also a mutual support and help in the forest. Indeed, very often the members of a forest ecosystem provide help and protection to each other.

All the above relations among the members of a forest ecosystem lead to a short-term balance which, in the long-run, is subject to constant variations and changes.

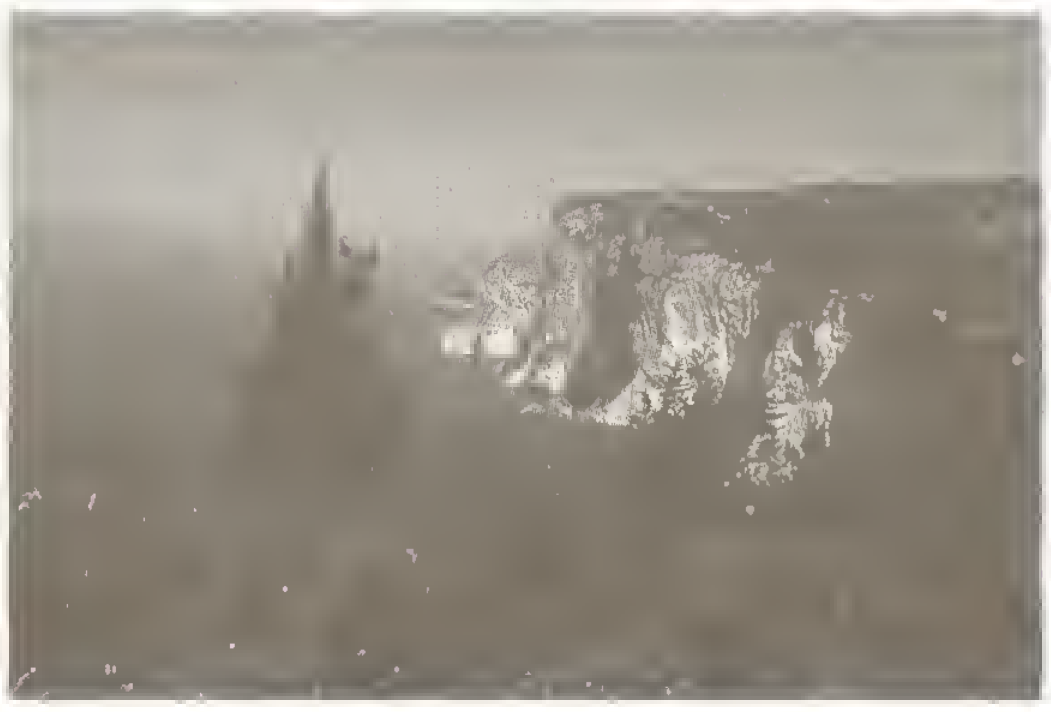
FORESTS IN GREECE

Introduction

The forest vegetation in Greece varies significantly depending on the region. The low altitude coastal zones have different vegetation than the semi-mountainous or mountainous areas. The vegetation of each area is determined by the species flourishing under the conditions of each area and the human interventions in the area.

Ecological conditions and forest biomes in Greece

Because of its geographic position (from the 36° to the 42° parallel of latitude), Greece is characterized by a variety of climate types. The climatic conditions are affected significantly by the sea and the common weather phenomena. The term



that is used to describe the Greek climate is **"Mediterranean Bioclimate".** Depending upon the distance from the sea, geomorphology and other parameters, there is a variety of climatic variations. As a result, Greece has a wide range of ecological conditions. In the vertical sense, (from sea level to the mountain peaks) the climatic variations (fall in temperature and increase in humidity) bring about changes in the forest and plant biomes.

The species that make up each one of these biomes have a number of natural adaptation mechanisms allowing them to survive and reproduce in the ecological conditions of their area. Of course, every species has its own ecophysiological behavior. However, within the same bioclimatic zone there are similarities among these biotic plants at least with regard to their adaptation mechanisms.

There are not clear limits between the successive biomes. Depending on the climatic and microclimatic conditions, the altitude range of the biomes varies. It is also possible that two types of biomes coexist forming "transitional zones". Unless such a zone exists, the variations of the ecological conditions are sharp.

The aspect and composition of the species of each biome depend on the effect of the flora of the greater area. In Greece, there is a great variety of vegetation species that combine the Mediterranean, Mid-European and South-European flora as well as the endemic species of the Balkans. The biome composition is affected by the soil and the human interventions. Consequently, in areas that are potentially suitable for the distribution of some species, these are extinct or replaced by other non indigenous species. **Therefore, the creation of plant biomes in our country depends on the biological and geographical reality.**

Forest biomes in Greece

In Greece, from the warmest to the coldest areas and from the lowest to highest altitudes, the following forest biomes are found:

A. Thermomediterranean sclerophyllous broad-leaved forests (Quercetalia ilicis)

They appear from the sea level up to 700 m altitude.

Maquis vegetation

It is found in the most humid areas of the Thermomediterranean zone, where human pressures

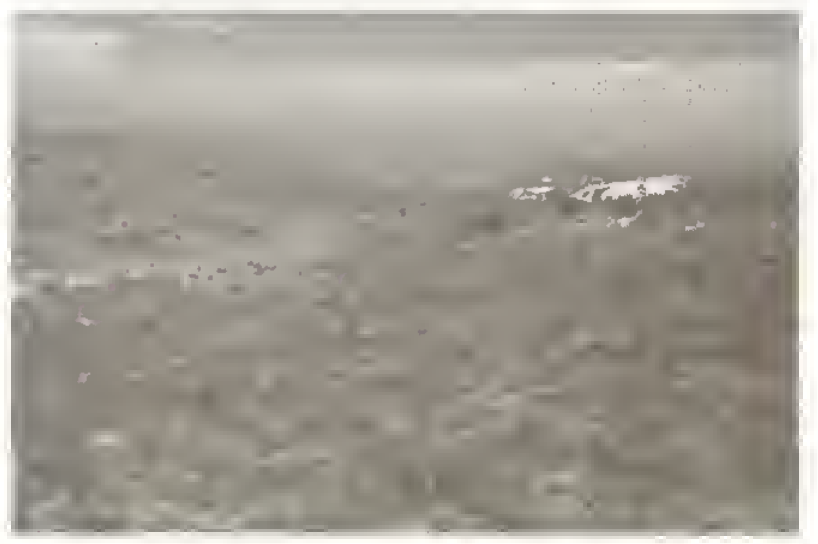
are not so devastating and consists of low plants (1-3 m). Such phenomena as fire and pasture keep the vegetation low. Given that the dry period is long in these areas, plants developed a strategy aimed at regulating the water balance during the dry periods. It consists of developing a large root system that penetrates deep into the ground to maximize water uptake and soil use. Moreover, through morphological, histological and physiological leaf adaptations, plants succeed in reducing their transpiration. The species that occur in this category are the following:

- *Pistacia lentiscus*
- *Quercus coccifera*
- *Quercus ilex*

Depending on the microclimatic conditions, the *Pistacia lentiscus* mixes with the *Ceratonia siliqua* and the *Myrtus communis*. The *Quercus coccifera* coexists with the *Phillyrea latifolia* and the *Quercus ilex* with the *Fraxinus ornus*.

Other characteristic maquis plants are the *Arbutus* sp., the *Erica arborea*, the *Olea europaea* var. *sylvestris*, the *Spartium junceum*, various types of *Juniperus* and the *Cupressus sempervirens*.

Phrygana



They occur in the dryer areas of the Thermomediterranean zone where the initial vegetation was degraded due to fire and pasture. The low and low density phrygana shrubs give a special aspect to the area. Their main ecological adaptation strategy is bimorphism. The main types of phrygana are:

- *Cistus* sp.
- *Phlomis* sp.
- *Sarcopoterium spinosum and Thymus* sp.

Other typical types of phrygana are *Euphorbia* sp, *Lavandula* sp., *Callicotome villosa* etc.

In the Thermomediterranean vegetation zone are found the forest types of *Pinus brutia* and *Pinus halepensis*. These forest types form the final ecosystem (Klimax) of pyrogenic succession. Both species are highly resistant to drought.

B. Paramediterranean vegetation zone (Quercetalia pubescentis)
(Deciduous broad-leaved forests of semi-mountainous and mountainous zones)

They consist of deciduous trees, mostly *Quercus* sp., and other broad-leaved species (except from *Fagus* sp.). The land covered by these forests accounts for 30% of the total forest land in Greece. The deciduous broad-leaved

forests are dominated by *Castanea sativa*. In northern Greece, some other species occur like *Tilia* sp., *Carpinus orientalis*, Sorbus torminalis etc.

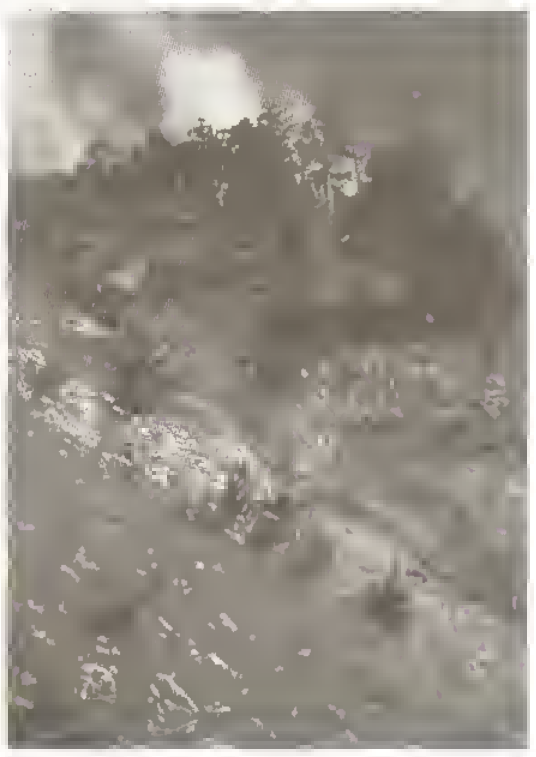
C. Zone of beech and mountainous Paramediterranean coniferous forests (Fagetalia)
(Deciduous broad-leaved forests and coniferous of mountainous areas)

This zone succeeds the previous one all over Greece. In S. Greece, where the climate is dryer and the Mediterranean flora predominates, the most common species is the forest type of *Abies cephalonica* while the *Fagus* sp. is not found at all. In the cold and humid areas of N. Greece, which are influenced greatly by the Mid-European ones, the predominant species are *Fagus* sp. and *Abies borissi regis*.

D. Zone of cold resistant conifers (Vaccinio - Picetalia)

The zone occurs in the high mountains of Northern Greece. The following forest types occur in this zone:

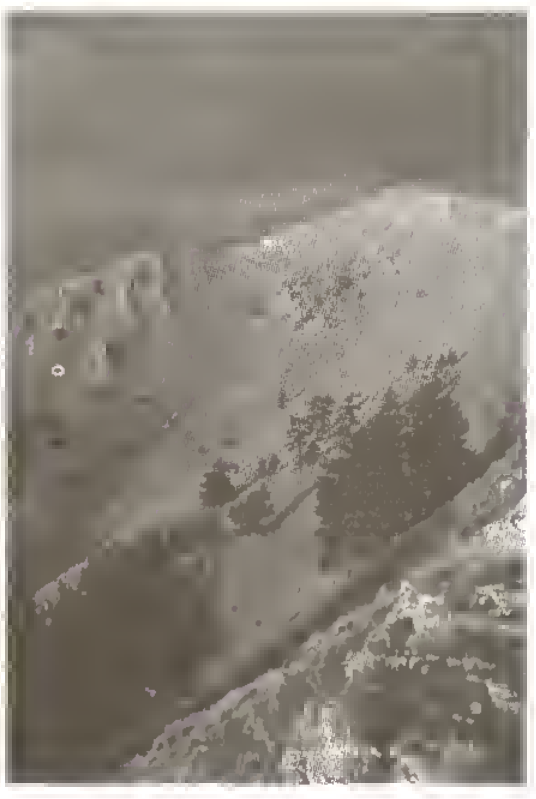
Pinus sylvestris - Picea excelsa



Pinus sylvestris forests occur in areas in the north of Olympus, in Pindos and along the northern frontiers of our country. In Rhodopes, *Pinus sylvestris* is found mixed with *Picea excelsa* and *Fagus sylvatica*. In the same area, *Picea excelsa* forms pure clumps.

Pinus heldreichii

The *Pinus heldreichii* grows happily at altitudes over 1500 m and up to the limits of the tree forest vegetation with the alpine forests (Olympus and Pindos range). In Pindos it is found mixed with *Fagus* sp., *Pinus nigra* and *Abies* sp.



E. Non-forested zone of high mountains (Alpine rangelands)

These are low, shrub lands dominated by *Juniperus nana*, *Arctostaphylos uva-ursi*, *Daphne* sp. and other shrubs. The shrubby vegetation grows above the forest limits where trees cannot thrive. The alpine flora is characterized by non-woody, meadow grasses.

F. Azonal vegetation

The above vegetation zones are based on climatic and altitude parameters. Apart from these vegetation types, there is also another type that is mostly linked to the soil conditions and human interven-

tions. It includes the Moor levels, grasslands etc.

Types of riparian vegetation

The vegetation that develops in the riparian areas of the Greek rivers. Because it depends on water existence, the riparian vegetation does not have a large distribution. Given that the initial distribution areas were used for agricultural cultivations, this type of vegetation was deforested to a great extent.

FORESTS OF RODOPI MOUNTAIN-REGION

Overview

Rhodopes mountain-region is a natural boundary between Greece and Bulgaria covering a total surface of 18.000 sq. kms. The range is divided into two sub-sections - the Western and the Eastern - that have different climate and landscape characteristics. Even though the range forests are better preserved than the other European forests, they have not been proclaimed National Parks. According to the Bulgarian National Strategy for Protection of Biodiversity, the Action Plan for Biodiversity Protection and the conclusions of published studies that were carried out in the Greek part of Rhodopes, today, the range is one of the most valuable ecosystems in the Balkans and in Europe, in general.

For millions of years, the range mountain mass was subject to climatic and geomorphological changes resulting in the creation of isolated, small or big biotopes of a particular ecological, plant and animal interest: the extended and highly productive natural Greek and Bulgarian forests, the only Greek Birth forest, the undisturbed natural ecosystem of Frakto Virgin Forest, the Tsihla forest, the great variety of growing types, the typical forest fauna of the cool season forests, the southernest distribution limits of a number of plants and animals make the area special.

Because of its position, Rhodopes is located in the cross-road of the Balkanic, Irano-Caspian and Southern Mediterranean flora and fauna and, consequently, has a very rich flora and fauna. More precisely, the vegetation consists of many endemic, rare and endangered species that are listed in the Eu-

ropean red lists, the Red Data Book of Bulgaria, the Red Data Book of Greece and in lists of protected plants. Evidence of this is the discovery of 27 new types of orchids in Tschervenata stena (Bulgaria).

Endemism is another factor indicating the importance of the area. Many endemic plants are named after the area (*Viola rhodopaea, Lilium rhodopensis, Haberlea rhodopensis* etc.). Besides, many plant species that are mostly found in other phytogeographic regions occur on Rhodopes mountains, like a number of arcticoalpine, Northern or Mid-European species. According to estimates, the number of plant species and subspecies living on the mountain range are over 1100 taxonomic units. A few kilometres away from the sea- bitten valley of Thrace, the area of Rhodopes is the southernest distribution limit of many Northern orders like *Abies alba, Picea excelsa, Betula pendula* etc.

The humid, silent and dark forests of the area house a typical Mid-European forest flora (and fauna) making up a wonderful diversity medley.

FLORA OF THE RODOPI WOODLANDS

In the lower part of eastern Rhodopes, as well as in its lowest southern part, the Coccifero-Carpinetum orientalis association can be found, which belongs to the Quercetalia pubescentis zone. Vegetation is mainly composed of shrubs; the following species dominate: *Quercus* cocccifera, *Carpinus orientalis, Juniperus oxycedrus* ssp. *oxycedrus.*

***Juniperus oxycedrus* ssp. *oxycedrus* (Berried or Prickly juniper)**

An evergreen monoecious shrub with linear needles growing in successive whorls of three along the twig. It produces spherical berries, red with a bluish tint. It is widespread in southern Europe and the Mediterranean coast. It is found all over Greece.

Carpinus orientalis (Oriental hornbeam)

A deciduous monoecious species; its leaves are alternate, with a serrated margin. Male and female flowers grow in separate catkins. Female flowers are in dichasial catkins. The fruit is a small nut held in a leafy bract.

It is a resilient, calcicole plant. It occurs in the warmest areas of the para-Mediterranean vegetation zone. It is found throughout mainland Greece.

At higher altitudes (up to 1,200m) there are woodlands dominated by deciduous broadleaf trees (Quercetalia pubescentis), and more specifically: *Quercus frainetto, Quercus petraea, Quercus cerris, Ostrya carpinifolia, Carpinus betulus,* among others. Other species, of a sporadic presence, include: *Sorbus domestica, Sorbus torminalis, Rhus coriaria, Acer monspenssulanum, Pistacia terebinthus, Pyrus amygdaliformis, Fraxinus ornus, Corylus colurna, Acer tataricum, Paliurus spina christi, Populus nigra* etc.

Quercus petraea (Sessile or Durmast oak)

A deciduous monoecious species with alternate leaves. Male and female flowers grow in separate catkins. Its stalkless fruit (acorn) is borne in a cup-like structure, the cupule.

It is widespread in the Balkans and further East, as far as northern Irak. Found in the mountains of northern Greece. It requires deep, loose, fertile soil. Moderately light-loving, vulnerable to late frosts when young.

Quercus frainetto (Hungarian oak or Italian oak)

A deciduous monoecious tree, with alternate leaves. Male and female flowers grow in separate catkins. The acorn is borne in a cupule and matures in about 6 months.

It is found all over Greece. It requires deep, humid, fertile soil. It can grow in semi-shade or no shade and prefers more humid and cooler conditions compared to *Q. pubescens*. Slow growth rate when young.

Carpinus betulus (Hornbeam)

A deciduous monoecious species; its leaves are alternate, with a serrated margin. Male and female flowers grow in separate catkins. Female flowers are in dichasial catkins. The fruit is a small nut held in a leafy three-lobed bract.

It requires deep, humid, loose and fertile soil. Can grow in the shade and withstand frost and wind. It is found in all the mountainous areas of Greece.


C. betulus


O. carpinifolia

Ostrya carpinifolia (Hop hornbeam)

A deciduous monoecious species; its leaves are alternate, with a doubly serrated margin. Male and female flowers grow in separate catkins. Female flowers are in dichasial catkins. The fruit is a small nut fully enclosed by the bracts as if in a small bag.

It is found in almost all the wooded areas of Greece. A resilient calcicole species.

It occurs in the warmest areas of the para-Mediterranean zone, mostly in dry, rocky slopes.

Fraxinus ornus (Flowering ash or Manna)

A deciduous tree, with opposite phyllotaxy; simple, pinnately compound leaves. White flowers borne in panicles. The fruit is a paddle-shaped samara. It is found all over Greece. Light-loving, fast growing, can grow in rocky spots.

At higher altitudes there are pure *Fagus* woodlands or mixed woodlands made up of species of the *Fagus*, *Pinus* and *Abies* genus. The dominant species in this zone are *Fagus* sp. Other species, of a sporadic presence, include: *Sorbus aucuparia, Sorbus aria, Sorbus umbellata, Acer pseudoplatanus, Acer platanoides, Acer hyrcanum, Populus tremula, Salix caprea* etc. The understory is mostly made up of *Neottia nidus avis*, *Muscari comosum, Scilla bifolia, Centaurea affinis* ssp. *affinis, Achillea millefolium, Digitalis viridiflora, Trifolium alpestre* etc.

Fagus sylvatica (European beech)

A deciduous monoecious tree, with alternate leaves. Male and female flowers grow in separate catkins. Its fruit is a nut enclosed in a spiky involucre. In Greece, it is found in the northern and central mainland. It requires humid, fertile soils, rich in organic matter. Cool season tree, soil improving, easily grows in the shade, forms a thick crown.

Populus tremula (Aspen)

A deciduous monoecious tree, with alternate leaves, almost round. The petiole is flattened sideways. Monosexual flowers in catkins. The fruit is a capsule, borne on a stalk. In Greece, it is found in mountainous areas, as a pioneer species. It requires humid, wet, loamy and sandy soils, mainly found on river banks. Light-loving, can withstand both frosts and heat waves.

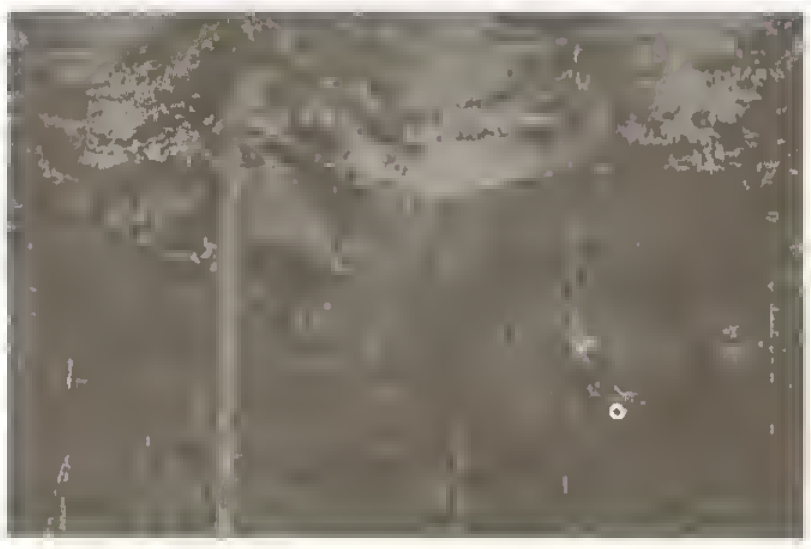
Betula pendula (Silver bitch)

A deciduous monoecious tree, with alternate, triangular leaves. The veins end at the edges, which are deeply serrated. Monosexual flowers in catkins. The fruit is a paddle-shaped samara. The white bark is characteristic in that it peels off in strips. It can grow in arid, infertile soils but its

development is better in humid, deep, loamy/sandy soils. It is very demanding in terms of light and can sprout runners around its base after a fire. A pioneer cool season species, it can create a pre-forest.

In areas between the geographical zones dominated by beeches and deciduous broadleaf trees, *Pinus nigra* woodland develops due to the particular geological and soil conditions prevailing there (e.g. Fraktos wood).

Pinus nigra (Black pine)



An evergreen, monoecious tree with needle-like leaves, in clusters of 2, twisted. Almost stalkless cones. Resilient, capable of developing in arid, infertile soils. Semi-shade plant. Mostly appears on lime or serpentine substrates at altitudes between 600 – 2,150 m.

Large areas are covered by woodland of the subalpine conifer zone (Vaccinio-Picetalia), more specifically of the Vaccinio-Pieion sub-zone, forming pure *Pinus sylvestris* stands as well as mixed stands made up of *Fagus sylvatica* and *Picea abies*. In the Bulgarian part of Rhodopes and certain spots in the Drama virgin woodland and the Koula area, *Pinus peuce* also appears. Woody vegetation includes the following species: *Juniperus communis, Taxus baccata, Rubus idaeus, Salix caprea, Rosa pendulina, Rosa pimpinellifolia, Betula pendula*. The understory is mainly composed of: *Vaccinium myrtillus, Vaccinium vitis idaea, Trifolium medium* ssp. *balcanicum, Crocus veluchensis* etc.

Abies borissi-regis (Macedonian fir)

An evergreen tree with two-ranked needles. Cylindrical oval cones. Native to the Balkans, shade resistant, with requirements similar either to those of poplars or those of *Abies cephalonica*.

Picea excelsa (Common or Norway spruce)

An evergreen, monoecious tree with needle-like leaves, which often become twisted resulting in a spiralling effect. Cylindrical hanging cones. It is widespread in northern and central Europe. In Greece, it is only found in Rhodopes. It requires humid soils and high relative humidity. Tolerates semi shade, is vulnerable to frosts when young.

Pinus sylvestris (Scots pine)

An evergreen, monoecious tree with needle-like leaves, in clusters of 2, twisted.

Cones with a curved stalk. Widespread throughout Europe. In Greece, it is found to the east of

mount Olympus, at high altitudes.


P. sylvestris

Apart from zonal vegetation, the Rhodopes mountain range also presents azonal vegetation, such as flat moors, grasslands and riparian vegetation. Flat moors are found in Haïntou, Lepida and Elatia, in pure *Pinus sylvestris* woodland and mixed *Pinus sylvestris* and *Picea excelsa* woodland. These moors are common in central and northern Europe; their presence in the southern Balkans is of great importance from the point of view of their special flora composition and also because they are the southernmost example of a typical northern vegetation type.

It should be noted that riparian woodland subbiomes are dominated by *Alnus incana* ssp. *incana*, *Salix* sp., *Alnus glutinosa* and, at lower altitudes, *Platanus orientalis*.

***Alnus glutinosa* (Black or Common alder)**

A deciduous monoecious tree, with alternate leaves. Flowers in dichasial catkins. Its fruits are woody 'false cones". Found in humid spots near streams or rivers throughout Greece.

Light-loving. It requires deep, loamy/sandy, humid soil. Young plants are sensitive to drought and late frosts.

***Platanus orientalis* (Oriental plane)**

A deciduous tree with simple deeply lobed leaves (almost to the middle of the leaf). Monosexual flowers in inflorescences (flower heads). Spherical fruit borne in clusters of 3-4. It is found throughout Greece, near rivers and streams.

Fast growing species; it requires deep, humid, fertile soil but can grow in slightly dry soil, too. It prefers sunlit spots and is resistant to frost and pollution.

RANGELAND ECOLOGY

Introductory definitions

Rangelands are natural ecosystems covered by herbaceous plants or shrubs and producing grazable forage for livestock and wildlife; they are also important for a number of other reasons such as hunting, water resources, environmental protection, leisure activities etc.

Rangeland ecology is a scientific field concerned with the study of the structure and function of rangeland ecosystems.

Economic importance

The economic importance of rangelands is manifold:

- They produce forage for livestock animals as well as wildlife.
- They produce water acting as hydrological basins for streams and rivers.
- They provide a range of indirect benefits such as: prevention of erosion in the mountains, leisure activities and oxygen production.

Typology and description of rangelands

Typology of rangeland plants

Rangeland plants fall into two main categories: **herbaceous** and **woody**

Herbaceous plants are further distinguished in **grasses**, **grasslikes** and **forbs**.

Woody plants are **bushes** and **trees**.

Hierarchical levels of rangelands

FORMATION → SUBFORMATION → SERIES → ASSOCIATION

Rangeland typology

There are four types of rangeland in Greece:

- Grasslands
- Heathlands
- Shrublands
- Wooded rangelands

Grasslands

Grasslands are ecosystems covered mainly by herbaceous plants. From a biomass point of view, it is grasses that dominate; from the point of view of species diversity, forbs present the greatest variety.

From an ecological point of view, grasslands can be distinguished in "climax" and "successive" communities.

Climax communities are found in areas with specific climatic conditions that prevent the succession to a forest whilst allowing herbaceous plants to flourish.

Successive communities are grasslands that have developed after the destruction of a woodland and remain in a relatively stable condition by various natural or anthropogenic means, e.g. floods, mowing, grazing, and other processes that prevent natural woodland from setting in.

Vegetation species in grasslands are very diverse, and include annual and perennial plants.

Grasslands in colder areas are dominated by C_3 species, known as **cool season** grasses.

Grasslands in warmer areas are dominated by C_4 species, known as **warm season** grasses.

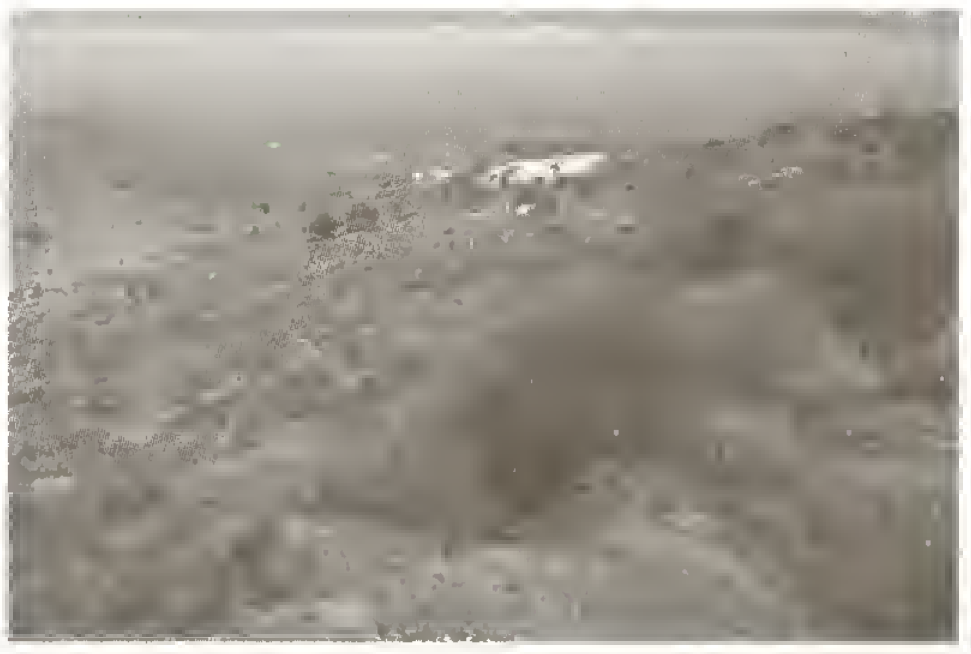
The annual production rates of grasslands depend on the following factors:

- climatic zone
- vegetation composition
- soil type
- use rate by grazing animals.

The main use of grasslands is grazing and browsing by livestock (sheep and cattle) and wild animals (mainly hares and partridges). They also provide other benefits such as water production, soil protection and leisure activities.

Heathlands

Heathlands are rangelands where heathlike plants dominate, also known as "phrygana".



Heathlands are quite unique ecosystems, which develop in the driest, hottest parts of the Mediterranean climatic zone, in areas with shallow rocky soil. They mostly derive from woodland ecosystems that have been degraded due to anthropogenic factors, mainly fires and overgrazing.

The main phrygana species characteristic of Greece's heathlands are:

1. *Sarcopoterium spinosum*
2. *Phlomis fruticosa*
3. *Corydothymus capitatus*
4. *Cistus* spp.

A large number of herbaceous plants are also found in heathlands. Annual production in heathlands is relatively low, despite the fact that above-ground biomass is quite high. This is because phrygana are not desirable forage plants for livestock. Heathlands are however important rangelands for livestock and game animals during the winter months. They are also ideal for apiculture, are of high aesthetic value and the plants' roots stabilize the soil and protect it from erosion.

Shrubland

Shrublands are rangelands where shrubs dominate.

From an ecological point of view shrublands (just like grasslands) can be either climax or successive plant communities.

The environments in which shrublands are found are divided in two big categories:

- Desert areas
- Temperate areas

In the Mediterranean environment, and therefore in Greece, two main types of shrublands are found:

- **Shrublands with evergreen broadleaf shrubs**
- **Shrublands with deciduous shrubs**

Shrublands with evergreen broadleaf shrubs

They are found in areas with hot, long summers. The main vegetation species represented are strawberry trees, mock privet, kermes oak and heathers that are anatomically and physiologically adapted to dry conditions in the summertime.

A special series of shrublands are those where kermes oak shrubs dominate and which are found at higher altitudes and cooler environments com-

pared to other series.

Finally, there are also shrublands composed mainly of evergreen shrubs with needle-shaped leaves where various species of juniper dominate.

Shrublands with deciduous shrubs

These shrublands are found in areas with humid and sub-humid Mediterranean climate.

In these shrublands the following species dominate:

- *Carpinus orientalis*
- *Fraxinus ornus*
- *Cornus mas* or *C. sanguinea*
- *Pyrus amygdaliformis*

Annual rangeland production is significantly different between the various associations. In these rangelands, what is important is not total annual production, but available annual production, i.e. available as grazable forage.

In general, annual production in shrublands is high and in many cases it is a lot higher compared to grasslands. Shrubland, especially evergreen shrubs, are valuable sources of protein and other nutrients for animals during the winter but also in the summer when herbaceous plants dry out.

Apart from grazing, these rangelands fulfil many other important functions such as stabilizing and protecting the soil, regulating the hydrological features of drainage basins, producing firewood and contributing to landscape aesthetics.

Wooded rangelands

Wooded rangelands are rangelands interspersed with isolated trees, lines of trees or thickets.

Most wooded rangelands are artificial and the result of anthropogenic activities. They are mostly found in the edges of woods (due to overlogging) as well as around mountain villages and in the subalpine zone.

Wooded rangelands are multistory ecosystems, with a rich variety of species.

They are defined based on the species dominating in the overstory. In Greece, three types of wooded rangelands can be found:

- **Conifer rangelands**
- **Rangelands with evergreen broadleaf trees**
- **Rangelands with deciduous broadleaf trees**

In the conifer subformation the main series are *Pinus halepensis* with a shrubland understory and *Pinus brutia* with a shrubland or grassland understory.

In the evergreen broadleaf subformation the typical wooded rangeland is dominated by kermes

oak with an understory of herbaceous or heathlike (phryganа) plants.

Finally, the deciduous broadleaf subformation is represented by a number of deciduous oaks series, most typically by *Quercus macroplepis* (*Q. ithaburensis* ssp. *macroplepis*) with a heathland understory.

As a rule, annual production in wooded rangeland is higher compared to other rangeland types for the following reasons:

1. The soil surface layers are enriched by falling leaves resulting in increased productivity.
2. Trees stabilize the soil preventing the leaching of nutrients.
3. By their bulk and shadow, trees improve the microenvironment.
4. By producing fruit edible by animals, they increase the rangeland's grazing ability.

Their increased economic importance resides in the fact that the overstrory increases the duration of the growing period in the summer, which means that animals have access to fresh forage and shade for longer.

Apart from producing forage, these rangelands are also important because they provide wood, water, game, protection and leisure.

Grazed Woodland

The practice of grazing in woodland areas is common in many areas around the world, including Greece.

Grazed woodlands cannot be considered rangeland because grazing is a secondary use, ancillary to the main one, namely wood production. Grazed woodland includes two subformations, **conifers** and **broadleaf** species, the latter generally producing higher quantities of grazable forage.

RANGELAND ECOSYSTEM

Introductory definitions

A **rangeland ecosystem** is an organised functional unit with constant energy flow and circulation of nutrients between its biotic and abiotic components.

From a biological point of view every ecosystem is made up of:

a) **the biocommuntity** (plant community & animal community)

b) **the biotope** (climate & soil)

Structure of the rangeland ecosystem

To facilitate analysis and study of the rangeland ecosystem, we divide it in 5 structural units:

- Organic & inorganic substances
- Physical factors
- Primary producers
- Consumers
- Detritivores

Productivity of the rangeland ecosystem

Concepts and definitions

Primary productivity is the rate of conversion of the sun's energy into organic substances through the process of photosynthesis.

It is distinguished in gross productivity and net productivity. The former refers to total photosynthesis and the latter to net photosynthesis, i.e. excluding the photosynthetic processes used for plant respiration.

The ecosystem's net above-ground production is the rangeland production. This production can include green plants making up its living material and dried plants or plant parts making up dead material.

The part of the rangeland production that can be grazed by animals is called grazable forage.

The rate of accumulation of organic material in consumer organisms is called secondary productivity.

Biological cycle

Seasonal growth rates

A plant's biological cycle is composed of the reproduction phase and the development phase.

Alternating between the two is dictated by genetically defined rules, coordinated by hormones and affected by environmental conditions.

Phenology

The study of the timing of the various phases of a plant's biological cycle that are repeated on an annual basis and their triggers is called phenology.

These phases are known as phenophases or phenological stages. All the different phenophases make up the phenospectrum.

The emergence and succession of phenological stages is affected by: climatic factors, soil nutrients and light period.

Two groups of herbaceous plants can be distinguished based on the timing of the phenophases.

The first group develops in relatively low temperatures which means that the biological cycle starts in the fall and terminates its activity at the end of spring or at the beginning of summer (C_3 or cool season plants).

The second demands relatively higher temperatures, therefore its biological cycle begins in spring and terminates at the end of the summer (C_4 or warm season plants).

Grazing

Grazing is defined as the clipping of parts of plants or of whole plants by animals that feed on them.

Grazing intensity is defined as the degree/quantity of grazable forage removed by animals.

Three levels of grazing intensity generally apply: light, medium and high. These levels correspond to undergrazing, regular grazing and overgrazing respectively.

Grazing frequency is defined as the interval between two consecutive plant clippings or the number of clippings during a specific period of time.

Grazing season refers to the phase of the growing period during which grazing takes place.

Finally, selectivity means the preference shown by animals for a certain plant compared to all other available plants. These preferences are dictated by the animals' four senses (vision, smell, taste, touch), by their experience and habits as well as by environmental factors such as climate, topography and soil. Rangeland plants that are selected first by grazing animals and are productive are referred to as **"desirable".** Desirable plants must be resistant to grazing and

Παρόμετροι της βόσκησης κοι οι ολληλεπιδρόσεις τους

diseases and have a good seasonal distribution of grazable forage being produced.

Rangeland plants avoided by animals and not presenting the above characteristics are referred to as "**undesirable**" while plants falling between these two categories are '**moderately desirable**' or **"neutral"**.

Grazing resistance mechanisms

Through thousands of years of evolutionary pressure from grazing, plants have developed various mechanisms to withstand grazing. Resistance can manifest either through avoidance mechanisms (decreasing the likelihood of being grazed) or by tolerance mechanisms (facilitating recovery after being grazed).

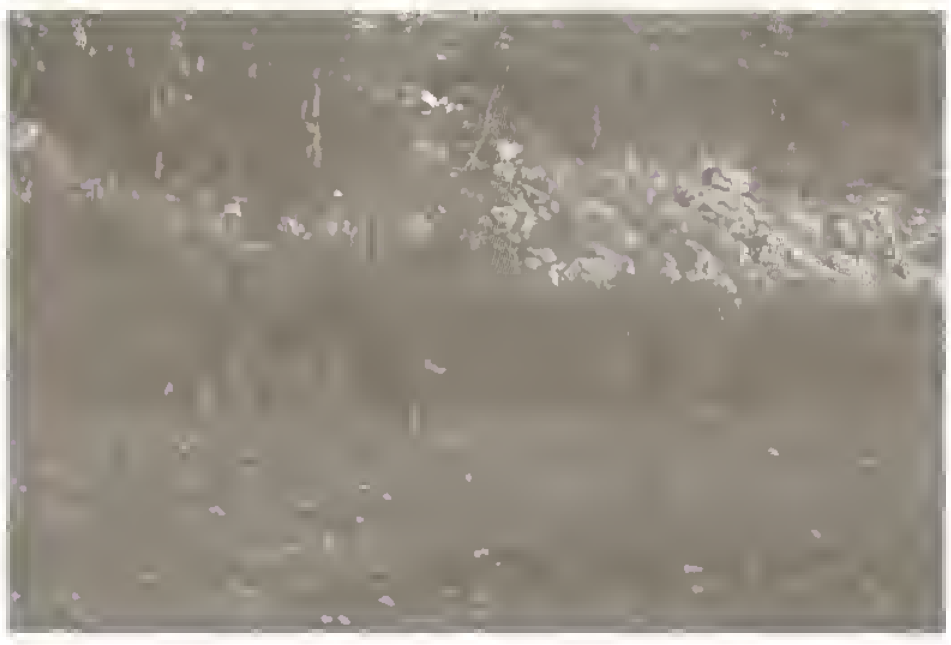
Grazing and composition of plant species

Direct effects

Grazing directly affects the composition of vegetation in rangelands. Selective grazing results in changes to the rangeland composition and less desirable or undesirable rangeland plants become dominant in the plant cover.

The degree of change inflicted on a rangeland's composition by grazing depends on the season, frequency and, more importantly, on the intensity of grazing activities. Light to medium grazing generally causes indiscernible to small changes. Overgrazing, on the other hand, generally causes major changes in the composition of plant species in a rangeland, which manifest as regressive succession ultimately leading to ecosystem degradation.

In general, changes in composition come about gradually. Desirable plants and plants most sensitive (morphologically or physiologically) to grazing are removed first. These plants are called **"decreasers"**. Less desirable plants are removed afterwards ("increasers"). This gives undesirable plants the opportunity to dominate ("invaders") thanks to decreased competition. If grazing continuous at an intense rate, even undesirable plants may be consumed, leaving nothing but bare soil behind.



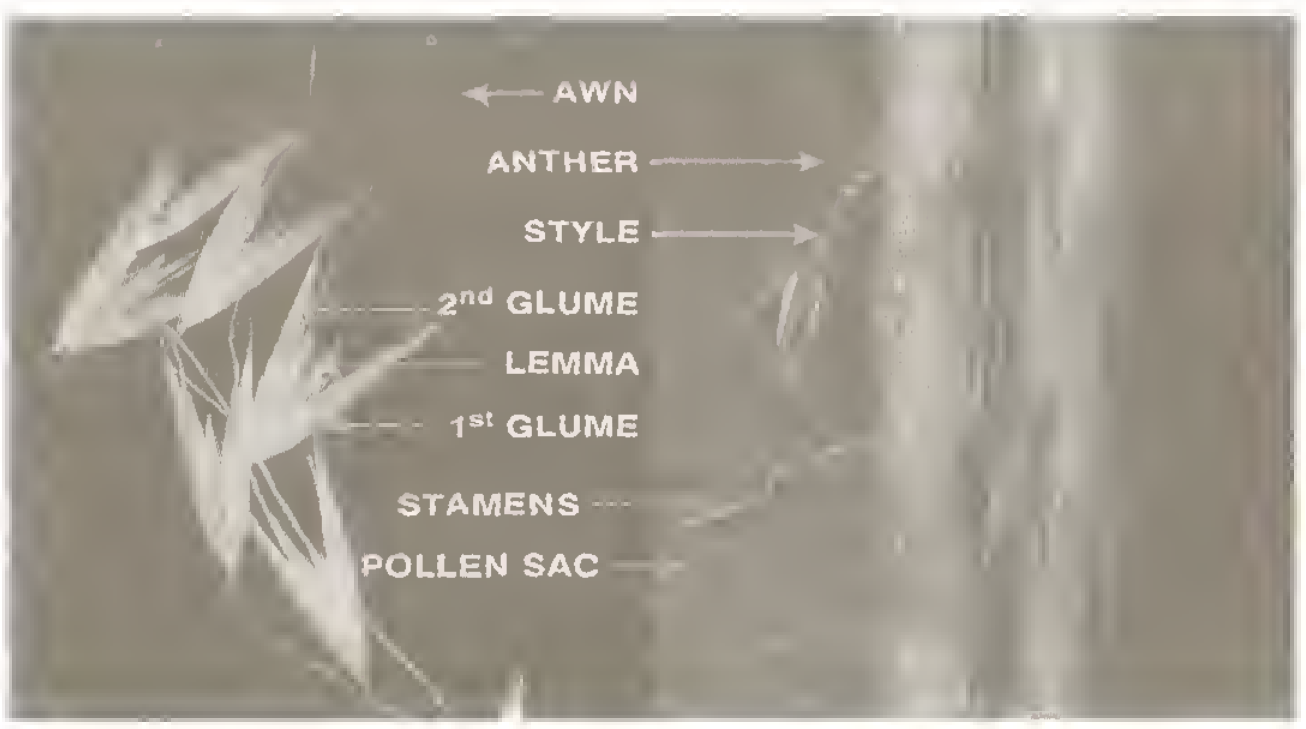
Grazing and rangeland production

The clipping of parts of plants or entire plants through grazing results in the decrease of grazable plant biomass and, consequently, of the entire rangeland production. The level of decrease depends on the vegetation's composition, and, to a larger extent, on the intensity and frequency of grazing. Production decrease due to grazing is expressed as the percentage of the weight removed and is called grazing rate or use rate.

MAIN RANGELAND PLANTS

GRASSES

This family of herbaceous plants is the most important one in terms of rangeland management because of the advantages presented by its taxonomic representatives. They are also important from an economic point of view because they include major crop plants (wheat, maize, barley, sorghum etc.)



Aegilops triuncialis

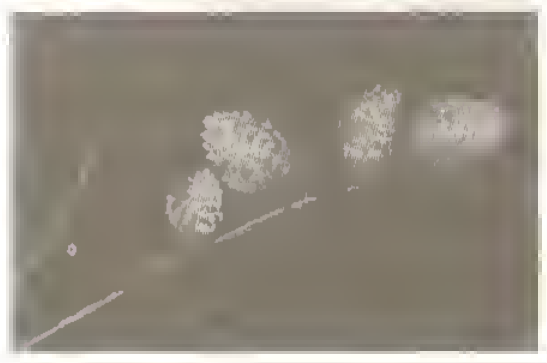
A low and middle zone plant, particularly xeromorphic that is often found in abandoned fields, along the edges of roads and on infertile soil. It is generally an undesirable plant for grazing because it produces very small quantities of grazable forage and its awns prevent animals from eating it, especially when ripe. It is an indicator of worsening rangeland state, a sign of overgrazing and its presence suggests a need to improve the rangeland.

Avena sterilis

A low and middle zone plant most often seen in deserted fields. It is relatively demanding in terms of nutrients and soil moisture. It is desirable for grazing as it produces large quantities of grazable forage, however, its awns prevent animals from eating it, especially when ripe.

Briza media

A mountain and pseudoalpine zone plant. It is not demanding in terms of nutrients and soil moisture. Moderately desirable plant for grazing as it produces moderate quantities of forage of moderate nu-



tritional value. It is mainly grazed by cattle.

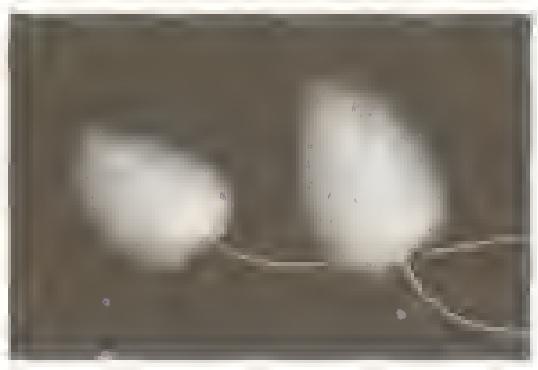
Chrysopogon gryllus

A warm season plant, of the low and middle zone. It is not demanding in terms of nutrients and soil moisture and is found in infertile areas. It is a moderately desirable plant for grazing because even though it produces large quantities of forage, it is of low nutritional value. Also, its large awns make it difficult for animals to graze. It is mainly grazed by cattle.

Dactylis glomerata

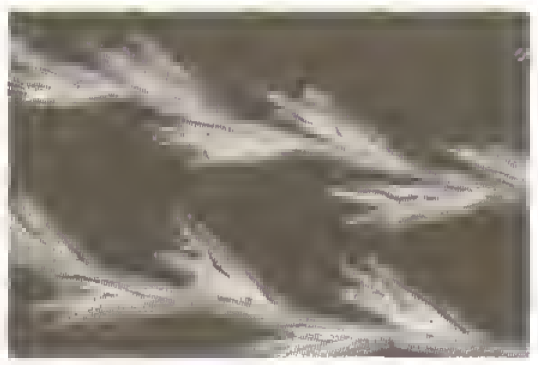
A plant that grows in all zones. It can withstand low temperatures and arid and shady conditions. It presents many different ecotypes. A desirable plant for grazing as it produces large forage quantities of particularly high quality. One of the most important rangeland plants that can also be used in pastures.

Lagurus ovatus



A low and middle zone plant, particularly xeromorphic that is often found in abandoned fields, along the edges of roads and on infertile soil. It is generally an undesirable plant for grazing because it produces very small quantities of grazable forage of low quality and its inflorescences prevent animals from eating it, especially when ripe. It is an indicator of worsening rangeland state, a sign of overgrazing and its presence suggests a need to improve the rangeland. It is of high aesthetic value and it is often used dry in flower arrangements.

Lolium perenne



A mostly low zone plant, which can grow in any zone. It is demanding in terms of soil nutrients and moisture and is sensitive to low winter temperatures. Generally, it is a desirable plant for grazing as it produces great quantities of grazable forage of relatively good quality. It is suitable for irrigated pastures.

Setaria viridis

A low and middle zone plant, particularly xeromorphic that is often found in abandoned fields, along the edges of roads and on infertile soil. A moderately desirable plant for grazing as it produces moderate quantities of grazable forage of relatively low nutritional value. Suitable for grazing in the summer, when all the other species have dried out. It is not capable of withstanding grazing pressure for long.

LEGUMES

Legumes are found in all the ecological zones of Greece, from seaside areas all the way to mountain tops. They can be herbaceous or woody, annual or perennial. Herbaceous legumes are an important grassland species, making up about 10% of the total number of their plant species. Among herbaceous species, annual legumes are the species marking the initial succession stages in rangelands and they are often the first species to colonise a bare or bunt soil surface. This is because they are light-loving and cannot withstand competition. Also, legumes cannot withstand grazing to the degree grasses can. Woody legumes are found in grasslands, but they are more dominant in shrublands. Most of these legumes are shrubs, trees being an exception.

Anthyllis vulneraria

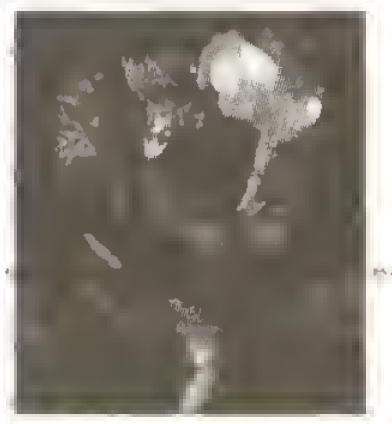
An annual or perennial herbaceous plant, with stems partly crawling on the ground and partly erect, covered in short silky hairs. A valuable forage species. It is also considered to have healing properties for wounds and abrasions. It is found in infertile areas.

Coronilla varia

A perennial shrub up to 70 cm in height with herbaceous stems. It grows in dry, rocky areas all over Greece. It is a species that develops well in poor soils. It cannot grow in the shade. It is widely used to control erosion in side slopes along roads and disturbed areas. It produces high quality grazable forage.

Lathyrus cicera

An annual plant, 20-60 cm high, with smooth, slender pinnate stems. It is found in cultivated and fallow land all over Greece. It is resistant to drought. It flourishes in calcareous soils.



Medicago minima

An annual low-lying plant, 5-40 cm, with erect or spreading stems covered in thick white hairs. It is one of the most widespread lucernes in the Mediterranean zone and in dry temperate areas. It is found in dry sandy or gravelly sites, all over Greece. It provides grazable forage of good quality.

Medicago sativa

Perennial, 30-80 cm; multi-branched, stems erect or decumbent, stout woody rhizome penetrating deep into the ground. It is considered one of the main forage plants. However, the quality of forage or hay is not dependent only upon

protein content but also on how thick the stems are, whether they are hollow or solid and by the number of secondary branches. It is believed to originate from Media in Asia Minor. It was introduced in Greece during the Persian wars.

Melilotus alba

It is found in all open ecosystems, in a variety of soils, although it is most common in calcareous soils. It requires considerable soil moisture during sprouting and establishment but afterwards it is drought resistant. It is eaten by all animal species.

Trifolium purpureum

A plant species producing excellent quality forage. It is common in all temperate and Mediterranean climates. It sprouts in autumn and grows until the end of spring or the beginning of the summer. It is considered an excellent species for pastures. Its ability to grow in poor soils producing high quality forage and its extended growing period guarantee an increase in animal production. It is considerably resistant to cutting and grazing.

Trigonella corniculata

An annual plant, 20-50cm high, with a smooth, erect stem. It is found in cultivated and fallow land all over Greece.

Vicia cracca

It is widely used for production of grazable forage mainly for cattle. It is also considered a good bee plant as bees and butterflies are attracted to it for its nectar. It can also be used to control erosion.

Vicia sativa

An annual or biannual herbaceous plant, 30-80 cm, hairy, crawling or climbing. It is cultivated in almost all European countries, western Asia, northern Africa and other temperate areas. In Greece, it is cultivated for hay production and/or its fruit. It adapts and flourishes in a variety of soil/climate conditions in temperate countries. Its ability to withstand the cold depends on the variety. It is sown in autumn or in spring if there is a high probability of frost in the winter. It can be sown in combination with oat or barley.

FOREST FIRE

INTRODUCTION

Worldwide, forest fires are the main problem of the natural environment. Not only does the burning biomass damage the vegetation cover and cause soil erosion but also releases CO2 in the air (which is not retained by the green plants and is produced by the burning of organic substances) intensifying the "greenhouse effect" and the climate change (e.g. the destruction of the Amazon forests leads to the loss of a big quantity of water vapors that are retained by the tropical vegetation, radical reduction of rainfalls and gradual spreading of drought). In the last twenty years, some of the most devastating fires that lasted for weeks or months affected China (1989), the USA (1988, 1990, 1996), Australia (1989), the Amazon river (1993, 1994) and Indonesia (1997). 1988 and 2000 were the years with the most severe fire damage worldwide.

In the course of time, forest fires affected the natural environment leading to the emergence of new phytosocieties (e.g. the Mediterranean-type ecosystems) that need fire to recover and survive.

Some areas are affected by destructive wildfires yearly. Such areas are those with a Mediterranean-type climate e.g. Mediterranean countries, California (USA), some areas in Chile, South Africa and Australia. The media have the power to spread the images and the news of a fire worldwide. Moreover, fires offer a good occasion for spectacular images. Hence, passions are greatly stirred by the news which convey to people the dimensions of the problem.

A fire is a crucial factor of the Mediterranean ecosystems. The types of vegetation that are found

in such ecosystems have evolved a variety of strategies to survive fires. Examples of such strategies are the direct coppicing of many forest species like holm-oak, mastic tree and arbutus, which loose their surface in the fire and store seeds in their pine cones that are released after exposure to fire.

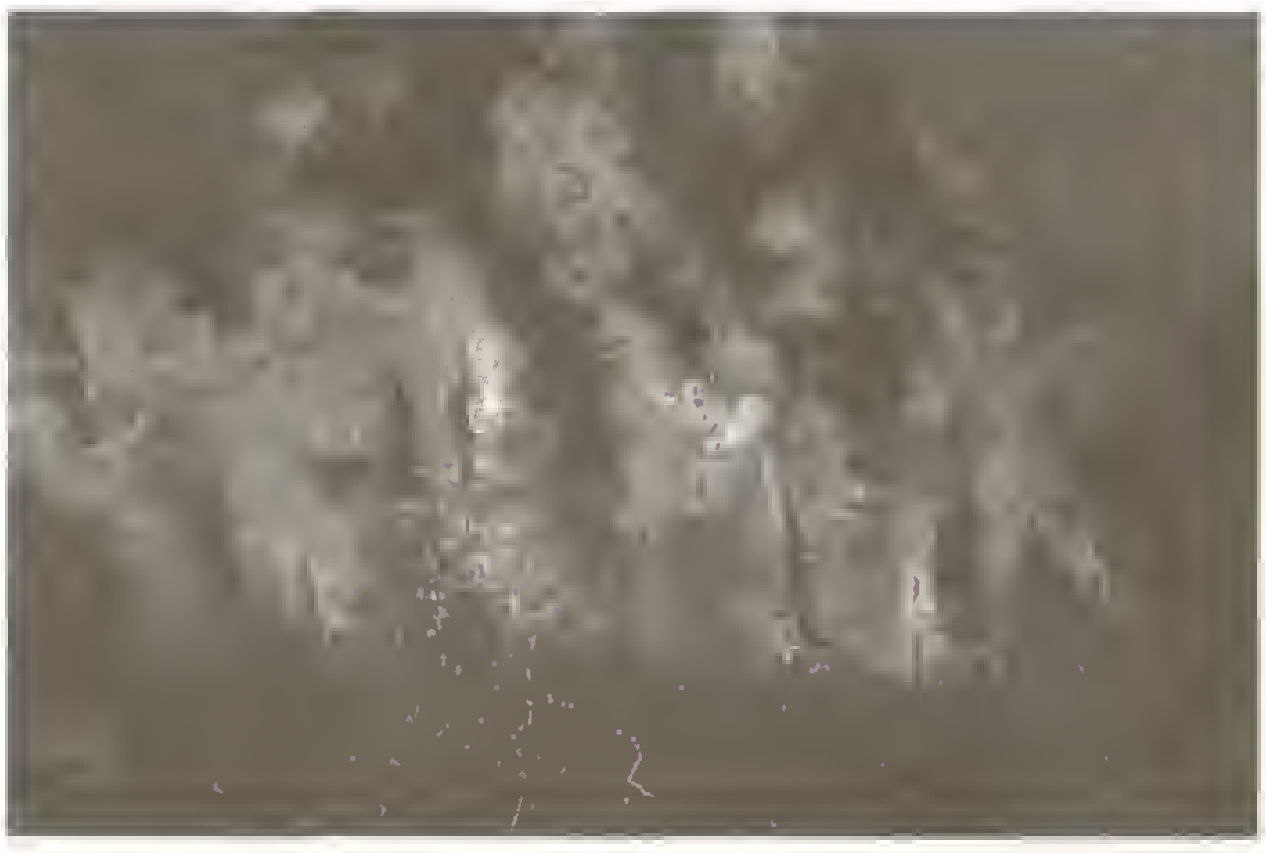
Unfortunately, human activities due to negligence, arson or economic benefit increase the fire incidence, which upsets the natural balance and the species succession and, in the long-run, degrades the forest ecosystems. If combined with overgrazing, fire incidence may be particularly destructive since the burned lands lose their soil and capacity to have rich vegetation. Consequently, they are transformed into downgraded rocky areas with poor biodiversity, low productivity and incapacity of protecting the lower altitude areas from flooding.

Apart from the Mediterranean countries, Australia and California, there are other tropical or subtropical (Indochina, Philippines, Amazonia in Brazil, Florida in the USA), continental (Montana and Idaho in the USA, Alberta in Canada), semi-deserted (Arizona, Nebraska, Utah in the USA) and arctic areas (Alaska, north-western Canada, Siberia) that are often affected by devastating and, sometimes even, fatal wildfires.

Nevertheless, it should be stressed that if a wildfire burns areas covered by vegetation without "disturbing" people's daily life (e.g. house, property and infrastructure destruction) it often escapes notice. For instance, the enormous wildfires that affected Indonesia in 1997-98 and lasted for months came to the fore only when it started threatening large cities and led to the closing of airports due to reduced visibility. Indeed, when a wildfire poses a threat to lives and property, it is in the limelight in a very short time.

WILDFIRE EFFECTS TO THE VEGETATION

Although it may sound strange, fire is indispensable for the natural function of most forest ecosystems, even those in Alaska, North Canada, Siberia and Scandinavia. Yet the fire occurrence of a specific forest ecosystem depends on the biomass accumulation rate, (e.g. the difference between the production of the biomass and its elimination), the probability of fire occurrence due to natural or human causes and the weather conditions favoring a fire's spreading. In most Northern, and Greek Alpine and Sub-Alpine ecosystems (fir, Picea abies, beech etc.) the accumulation rate is quite low; the human causes are limited while the natural ones (e.g. thunders) do not coincide with the weather conditions that are favor the fire's spreading. In such areas, the fire return interval may be over 200 or 300 years and presupposes that a stand is very old, trunks are broken or fallen etc. In these cases, fire acts as a cleaning agent and contributes to the regeneration of the forest. Under these conditions, in the intensively



managed forests, like the ones in Finland, Sweden, Germany, people have plenty of time to take wood for personal use reducing the probability of a destructive wildfire. Eliminating the fire occurrence results to a decrease in the biodiversity because many species that need fire to regenerate are wiped out. As a result, sometimes forest managers use prescribed burnings (controlled application of fire under specific conditions) to provide a certain balance.

This is not the case of the Mediterranean ecosystems, where the biomass accumulation rate is high and the fire cycle, depending on the vegetation and the specific conditions of an area, may be as short as 40-100 years (Trabaud et al.1985).

Greece's relief, in combination with the altitude variations, the sea impact that varies depending on the distance of each area from the sea and the large expansion (in proportion to the total surface) from North to South result in a particularly high biodiversity that is astonishing. For instance, the mountainous areas of the prefecture of Drama is the southernmost limit of *Picea abies*, known as Norway spruce; in Eastern Crete, there is a well-known palm forest, the Forests of Vai. The role of fire in such a great variety of ecosystems varies. Accordingly, the ecological impact of a fire may be acceptable or destructive depending on the fire, intensity, occurrence time, frequency etc. The last element is particularly crucial since human activities have increased fire frequency to such extent that even fire-adapted ecosystems such as the *Pinus halepensis*, the *Pinus brutia* or the evergreen broad-leaved plant ecosystems lose balance and the possibility of recovery and are constantly downgraded until soil erosion leads to desertification (Barbero et al. 1998).

The fire impact on the ecology of the ecosystems of shade-tolerant species such as fir and beech, found at high altitudes, has not been studied in dept. Nevertheless, in Greece, it is known that when these species are burnt they cannot recover easily because they are located in high altitude and big slope areas and risk being affected by erosion.

Lowland ecosystems

The lowland ecosystems are the ones that were studied in depth in relation to the fire ecology [(i.e. *Pinus halepensis*, *Pinus brutia* or the evergreen broad-leaved plants, spiny sub-shrubs (phryganα)]. Almost every research revealed their strong capacity of recovery and quick regeneration which, is due to the fact that their forest species are adapted to fire.

More precisely, these pine species always produce a certain amount of seeds on their crown (Naveh 1974). These seeds are released after exposure to fire providing the necessary regeneration material. If the shrub understory is burnt, the young pines face a low competition and manage to grow (Trabaud 2000). All these presuppose that the pine stands have reached the age of

Pinus halepensis cones that open and release seeds right after a fire episode

producing a big amount of seeds, i.e. 14 years old.

If a fire burns a regenerated stand is burnt at a younger age destroying every seed releasing tree in the area or in the edge of this area, the regeneration of the stand is difficult and requires reforestation (Izhaki and Ne'eman 2001). Among the broad-leaved evergreen thickets, the main species are *Quercus coccifera, Pistacia lentiscus, Arbutus unedo* etc., which have a different post-fire survival strategy.

This process is called coppicing and allows a burned area to regenerate one year at the latest after it is burned and to protect itself from soil erosion. Other types of turfs and low shrubs produce a high number of seeds that remain stored in the soil for many years until the elimination of shrub competition allows them to sprout (Daskalakou and Thanos 1996). Such species as *Cistus sp.* that occur massively after a fire in the evergreen thickets, grow very fast and protect the soil. However, very soon (3-4 years later), the coverage rate of the *citrus* sp. decreases giving way to the shrubs (Arianoutsou and Ne'eman 2000).

Post – fire regeneration takes place in shallow and rocky soils. There are 7 – 10 year old seeds. If seeds are over 10 years old, the slope is over 50% and all the needles are burned, regeneration becomes difficult.

At the age of 20 – 30 years old, regeneration depends on the existence of cones, seeds germination on the ground. In case of regeneration, they are replaced by evergreen broad-leaved plants that are re-burned (Goubitz et al. 2004). The *Pinus halepensis*, and *Pinus brutia* are serotinous: 10-90% of their pine cones remain closed for about 2 – 17 years. During a fire, the heat melts resins in the seeds that once held the cone or fruit tight shut, which then allows the structures to open and release the seeds (Thanos 1999).

Regeneration is not easy because cones open earlier. In the case of the *Pinus brutia* there are less fires but a double burned land as opposed to the

Pinus halepensis seeds are accumulated by wind in a pit that opened on the floor when a tree vine was burnt during a fire.

Pinus halepensis where the number of fires is four times higher while the burned land is half the size. This happens because:

1. As opposed to *Pinus halepensis, Pinus brutia* is found in distant areas, without roads or fire-fighting equipment.
2. The *Pinus brutia* is found in areas with lower pressure than the *Pinus halepensis*.
3. The *Pinus brutia* is found in more windy areas than the *Pinus halepensis*.
4. The *Pinus brutia* has larger voids the *Pinus halepensis* allowing in the wind.
5. The *Pinus brutia* has a bigger understory than the *Pinus halepensis* and has taller and branch-free trees than the *Pinus halepensis,* which has shorter trees with branches reaching the ground.

Other biological fire - adaptation mechanisms developed by plants (Bourdeau at al. 1987) are the following:

1. Fire prevention: *Pinus nigra* releases its seeds from March to April in order to have a canopy seed bank before the fire onset.
2. Thick bark: it serves as an insulation material reducing the thermo-conductivity to avoid burning the cambium.
3. Reproducing organs protection: no such plants exist in Greece.

FIRE EFFECTS ON THE PHYTOSOCIETIES

The phytosocieties succession stages are the following (Arian-outsou 1998):

1. Naked soil
2. Yearly grassland plants
3. Phrygana
4. Broad-leaved evergreen thickets
5. Light-demanding conifers
6. Light-demanding broad-leaved plants
7. Shade-demanding broad-leaved plants

Fire climax is the succession stage defined by the intensity and frequency of fires that either stops or delays the progression of succession. During the succession, a number of disturbances occur. The climax community depends on the disturbance frequency and intensity (Naveh 1975, Moreno and Oechel 1994).

DAMAGE AND PRIMARY EFFECTS

Apart from the ecological impact, forest fires cause direct damage implying economic losses of:

1. Human lives
2. Houses and infrastructure (roads, power supply network, telecommunications networks)
3. Crops (gorse, orchards, olive groves)
4. Livestock
5. Forest products (i.e. timber, resin, seeds etc.)

In addition, forest fires have primary effects:

1. They disturb the life rhythm during and after the fire (i.e. tourism)
2. Smoke is harmful to the health and life of the citizens and fire-fighters

In general, the direct consequences of the forest fires are limited to the fire-affected areas that are usually small. Yet, in the last decades, through the development of regions of first or second residence nearby forests or wooded lands, some small-scale fires proved excessively devastating. With regard to the fire damage, it should be pointed out that people are mostly concerned with the loss of their properties (houses and other infrastructure) and other State infrastructure (roads, power supply, telecommunications networks etc.). Even though such damage is usually limited, it is spread by the media that convey an exaggerating about the fire risk. As a result, people often feel very insecure and even afraid of losing their life. However, losing one's life or getting injured in a fire is far less probable than other risks, such as the car accidents.

Human loss

Human loss is less common in fires and usually affects fire-fighters or simple citizens. Forest fires spread fast and, under specific fuel (dense vegetation, low shrubs) or weather conditions (strong wind, low humidity), fire velocity exceeds the human speed (> 5 km per hour) causing death. Also, topography is a decisive factor (big soil inclination, close gorges etc.). Human loss or injury may also occur during the fire-fighting efforts due to the high environmental risks that exist in an area during a fire (road accidents, heat-strokes, monoxide inhalation, rock and tree falls etc.). Finally, aerial fire-fighting is particularly dangerous since the number of helicopter or plane pilots that lose their life or get injured is quite high because of the dangerous working conditions.

House destruction

House destruction due to fire varies depending on the country. The construction materials that vary depending on the available materials, the cost, the culture and the tradition of each country are significant factors. Therefore, in countries like the USA, Canada and Australia, hundreds of houses may be burned in a fire because they are generally made in wood. On the contrary, in countries like Greece, where houses are made in flame-resistant material (inert matter), the losses are much lower. This is not the case of the prefabricated houses or jerry buildings that become prey to the flames.

Economic loss

From an economic perspective, direct damage includes damage of private or state property. Also, fire may cause damage to crops (gorse, orchards, olive groves) and to the livestock. Such fires burn mostly stock-breeding facilities where animals are trapped and, to a lesser extent, free range animals. Regarding the loss of wild animals and birds, contrary to common belief, the loss is very low and practically inexistent respectively.

Cereals destruction

On occasions, fires have caused wide-scale cereals damage to big granaries (i.e.Nebraska State in the USA, Kilkis valley in Northern Greece) especially in the cases that it occurred prior to harvest, as a result of a combine harverster dysfunction. In such cases, the economic loss is confined to the loss of a year's harvest. However, if multiannual harvests of bearing trees and olive trees are destroyed, the economic loss is much greater and may have secondary effects as described below. If cultivated and cleaned properly, the olive groves are not easily burned. However, during the anti-fire period they burn very easily if the grass under them has not been removed. Also, vineyards are one of the crops that do not help fire to spread. Finally, the damage of greenhouses and other infrastructure (i.e. watering systems) implies great loss of capital for producers.

Loss or downgrading of forest products

Wildfires encompass a great economic loss from the damage and downgrading of forest products (i.e. timber, resin, seeds, etc.). The size of the damage depends on the fire type, the size of the burned trees and their possible uses (pillars, sawn timber etc.), and the decisions and actions taken with regard to the use of sawn timber after a fire.

The perception of the damage size varies significantly from one member state to the other depending on the forest ownership regime. Therefore, in areas with private productive forests (i.e. southern France), forest owners have established very strong associations aimed at protecting forests from fire. This also applies to large forest owning companies in the USA and Canada that provide fire-fighting means and personnel and share the fire-fighting cost with the Forest Service. The countries that have mostly public forests, are not directly concerned with the direct economic loss associated with the destruction of a forest.

SECONDARY EFFECTS IN RELATION TO OTHER DESTRUCTIONS

The secondary effects of fire are not minor. The most evident one is the sharp increase in the flood risk in burned areas and in areas located in the downstream of the burned areas. Fire clears soil from vegetation and, as a result, the rainfall water flows undisturbed causing erosion and sweeping along mud, stones, vegetation remains and, hence, devastating floods (Anderson et al. 1976). The fire-flood relation is obvious and a large number of examples from all over the world confirm it (Dias – Fierros 1990).

FOREST RECREATION & TOURISM

1. INTRODUCTION

Recreation is an activity or a pre-planned inertia that is pursued voluntarily.

As a deeper psychological concept, recreation refers to the aesthetic and mental experience resulting from this activity.

It differs from the activities aimed at gaining money and covering life needs. Also, it differs from other daily activities such as eating, sleeping, house cleaning etc.

Recreation's particular feature is not the activity itself but the mood of those who pursue it.

Also recreation is closely related to free time - leisure – but differs from it to the extent that leisure equals time while recreation is activity.

Recreation is divided into outdoor and indoor recreation.

Indoor recreation is the free-time activity that is pursued in a natural space rather than in an urban environment and aims at giving pleasure and mental and intellectual well-being. Diagram 1 illustrates the "Time/ recreational activity"ratio.

The outdoor forest recreation is an experience resulting from a complex interaction between on one hand, the individual, his objective, his education etc. and on the other hand, the natural- Outdoor recreation is not new. Such activities as hunting, fishing etc. date back from the antiquity. However, in the recent years, the participation in outdoor activities has increased signifi-

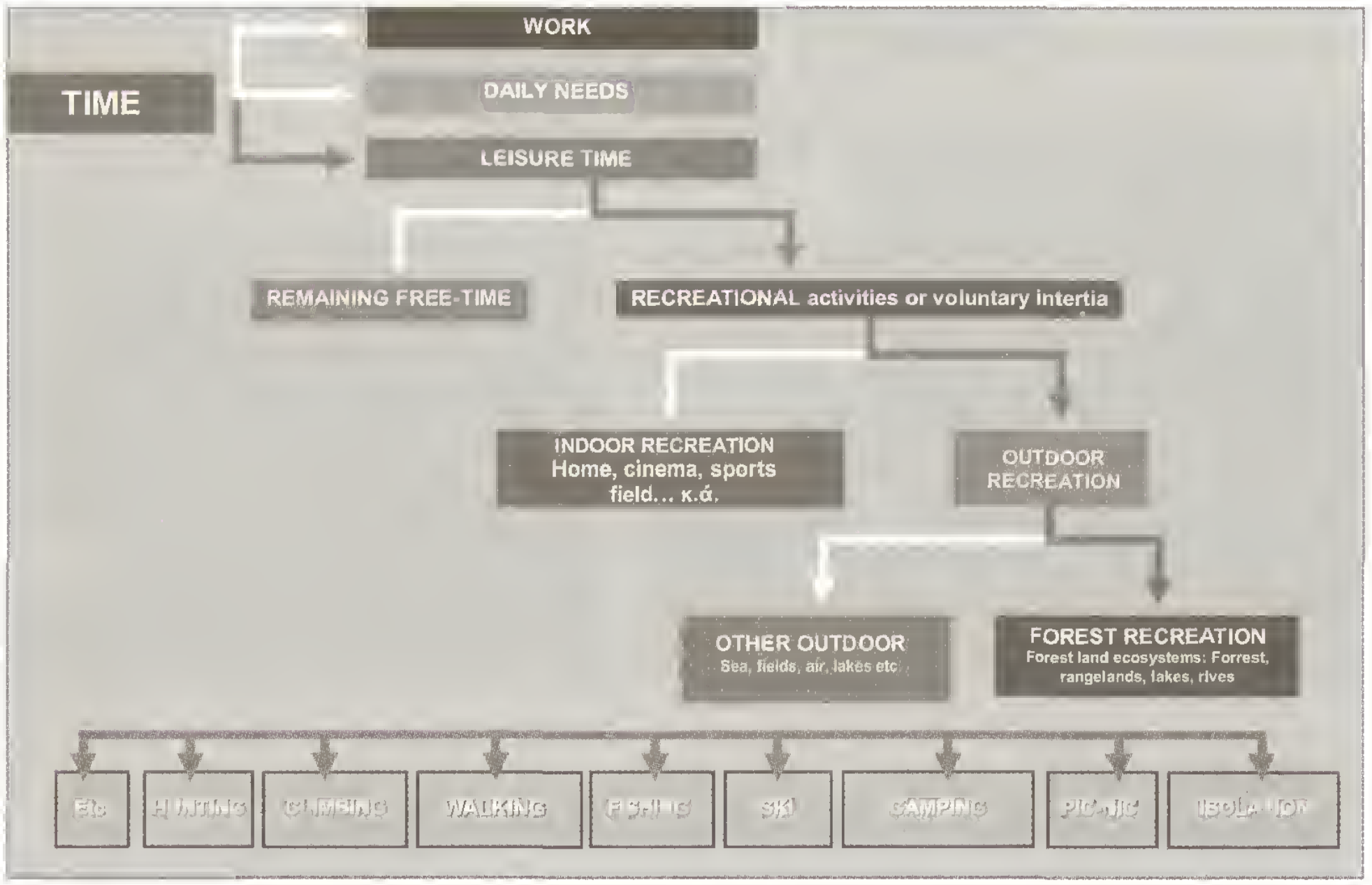


Diagram 1. Flow diagram: Time – Man – Forest recreation

cantly in the USA, Europe and also in Greece.

Outdoor recreation requires very often a quite few amounts of natural resources.

One of the resources that is significant for outdoor recreation is the forest. Forests have some characteristics that diversify them from other ecosystems. Their most important factor is the natural cover.

Vegetation:

- renews the oxygen,
- absorbs dust and noises,
- protects against wind and rain,
- moderates the extreme temperatures and
- provides ultraviolet ray-free shadow.

Apart from the great variety of their external appearance, trees form the third dimension of a landscape giving it a special character.

The forest develops many micro-environments that are suitable for serving a wide range of wild species.

The recreational activities that are pursued in a forest (in natural land ecosystems) are called forest recreation, which is part of the outdoor recreation.

This type of recreation includes several activities such as: hunting, fishing, walking, picnic, camp-

ing, climbing, skiing, isolation etc. *(see Diagram 1).*

2. THE NATURE OF FOREST RECREATION AND TOURISM

The outdoor recreation and tourism that are pursued in forests or natural land ecosystems is an important function of the forest ecosystem.

All developed countries manage forests and natural ecosystems in such a way as to offer recreational services to the people.

Some new recreational activities such as skiing, rafting in artificial and natural lakes, floating rivers etc. were added to the traditional ones (e.g. walking, climbing, hunting, fishing in rivers and lakes, observing and enjoying nature etc.).

The visitors' satisfaction degree and the landscape quality lead to an increase in the number of visitors.

This means that the recreational areas should have all the features that are necessary to satisfy the visitors' needs.

As a result, the recreational areas must be chosen very carefully. However, granting a simple visit permit is not always sufficient to satisfy the visitors.

It becomes clear, that in most cases, the areas need development and arrangement. This is the mostly the case of the high-frequency forests (suburban or close to large urban centres).

What would make a forest attractive for outdoor recreation or walking is above all, its natural characteristics (vegetation, fauna, topography etc.) and then the following:

- Forest proximity with the visitors' place of residence.
- Access to the forest (by car or by foot) and quality of the roads leading to the forest.
- Forest facilities: rest areas, parking, picnic areas, springs, WCs etc.
- Forest comfort and security (communication, first aid, etc.).
- Range of recreational activities offered.

2.1 MAIN FACTORS AFFECTING THE FOREST RECREATION

There are several factors affecting the demand for recreation.

The following factors are decisive for demand: social, economic, transport and time. There are some other important factors relating to the offer conditions such as: cost, range of activities, forest climatic conditions, forest capacity and competition (other recreational areas).

SOCIAL FACTORS

1. Size of population
2. Place of residence
3. Age
4. Education
5. Profession
6. Social conditions

ECONOMIC FACTORS

1. Disposal income
2. Travel cost

TRANSPORTATION FACTORS

1. Means of transport
2. Road quality (access)
3. Drive quality
4. Traffic conditions

TIME FACTOR

1. Free-time (leisure)
2. Access time

SERVICE QUALITY AND QUANTITY

1. Quality of recreational services
2. Number of services
3. Range of activities

CLIMATIC CONDITIONS

The climatic conditions in the visitors' place of stay and the forest affect the demand and its variation throughout the year significantly.

ADVERTISING

Certainly, wishing to visit a specific forest presupposes knowing of its existence, its characteristics and the recreational options it offers. That is why advertising is quite important for the demand of forest recreation. A forest may become known through the mass or personal media.

COMPETITION

Substituting the recreational services of a forest by those of another one creates competition

and affects the demand for recreation significantly.

FOREST CAPACITY

One of the most important factors affecting the recreation demand is the forest carrying capacity.

2.2 FOREST RECREATION TRENDS

The changes in the supply and demand of forest recreation affect its rational planning.

Given that the development works that are planned and carry out do not only aim to meet the present needs, the forest managers must take into account the future trends.

For doing so, the methods used to date are:

1. Extending the past changes in the demand (time series)
2. Extending the causes of the changes
3. Assessment based on the current visit data
4. Simple demand assessment
5. Recreation trends research

3. FOREST RECREATION RESOURCES

3.1 FOREST ENVIRONMENT SUITABILITY FOR RECREATION

To plan forest recreation, study and manage forest natural resources, the manager must be aware of and define some basic concepts and factors.

Such factors are the demand for recreation, the supply or suitability of natural resources and the recreation area capacity.

The forests and forest lands meet the modern man's needs for either informal (picnic, walks, enjoying the view etc.) or specialized recreation (hunting, fishing, climbing, study of natural history, skiing etc.).

The forest suitability (the correct term is capability rather than suitability, which depends on both supply and demand) for recreation must be examined in relation to a specific activity but depends on a number of factors such as:

- Climate, open spaces

- Soil inclination, topography
- Soil texture
- Accessibility
- Water supply

The above factors are decisive for most recreational activities.

For example, **climate** and weather conditions affect most of the outdoor recreational activities.

Most of the activities require **open spaces** in or near the forest.

With regard to the **soil inclination,** there are many activities that require a certain area. However, the higher the soil inclination, the less activities may be pursued.

The higher the variety of the topographic arrangement, makes higher the aesthetic value of a landscape and more attractive for most of the informal recreational activities.

Regarding the soil texture and drainage, the recreational activities require soil that may be easily reached by foot, car or horse (in the case of horse-back riding). As a result, the dry and easily drained low vegetation areas are preferable.

Another factor affecting most recreational activities is the accessibility of an area, expressed in the distance from the closest highway. But even the forest roads are suitable for such activities as walking, horse-back riding, car races etc.

Finally, water presence allows people to pursue a wide range of water-based recreational activities and improves the quality of the environment.

Apart from the above factors, there are others relating to the forest itself that also affect the demand for recreational activities.

Some of them are the following:

a) **Tree age and height**: When trees are still in the growing stage, the recreational activities options are very limited due to the damage risk. If the vegetation is dense, crossing is impossible. The more the trees mature, the higher the number of activities are possible.

b) **Flora diversity** makes the forest more attractive for recreation.

c) **The forest's capacity to provide protection against visual disturbance and noise,** and its capacity to provide protection from adverse weather conditions (excessive heat, rain and wind).

Another factor determining the suitability of a Greek forest for recreation is its distance from the urban centres and the sea resorts and the presence of a historical, religious or archeological site nearby.

From all the above, it becomes clear that the forest environment is very suitable for many recreational activities.

3.2 FOREST CLASSIFICATION BASED ON RECREATION

Forests and forest lands are classified in different categories based on the type of forest recreation they offer. This classification allows us to plan and use them in a more rational way. Below, follows the description of these categories according to Law 86/69, Law 996/71, Law 998/1979 etc.

NATIONAL PARKS

According to Law 996/1971, a National Park is a forested area which is of great interest from the aspect of wild fauna and flora conservation, geomorphological formations, substratum, atmosphere, waters and generally its natural environment.

In such areas, it is necessary to protect, conserve and improve their composition, form and natural beauty with a view to ensuring aesthetic, mental and hygienic pleasure, tourist development and allowing the implementation of any kind of scientific research.

To avoid confusion, the International Union for the Conservation of Nature and Natural Resources (10th Summit, New Delhi, India, 1969) stipulated that:

A National Park is a relatively large area where:

a) One or several ecosystems are not materially altered by human exploitation and occupation. The vegetative and animal species, geomorphical formations and the animal and vegetation ecological environment present great interest from a scientific, educational

and recreational point of view or offer a high aesthetic value landscape.

b) The competent authorities have taken all the necessary measures to protect it from any rational or intentional human intervention even if it aims at supporting and speeding up its natural development.

c) Visits are allowed only for cultural, educational and scientific purposes or for mental uplift or regeneration purposes.

Every National Park consists of a core and a peripheral zone. According to Art. 5 of Law 996/1971, the core is of ultimate protection and covers an area no less than 1,500 ha, except for the Parks founded in islands that can be smaller.

The peripheral zone is a similar area, at least as large as the core, where land use is compatible with the protection targets of the National Park.

AESTHETIC FORESTS

The term "aesthetic forests" i.e. recreation, health, walking, singular natural beauty forests (Law 996/1971).designates forests and natural landscapes that do not have the same characteristics with the national parks but are areas of a particular aesthetic, hygienic and tourist importance.

RECREATIONAL FOREST

A recreational forest is a small or large area where:

1) Landscape, vegetation, animals, geomorphic formations, flowing or stagnated water are of high importance and are suitable for recreation purposes. Based on the landscape architecture principles and tools, they may be turned into natural beauty landscapes without affecting greatly the other functions of the forest.

2) The competent authorities have expressed their will to arrange, conserve and develop the landscape with a view to providing recreation services.

3) The visitors are welcome to use the recreation facilities with respect to some rules and regulations.

NATURAL MONUMENTS

Public and private sites of particular paleontological, geomorphological and historical importance may be declared "protected nature monuments".

Protected Nature Monuments can be trees, tree stands, wetlands and rare plant species of particular botanical, geobotanical, aesthetical and historical importance (Law 996/1971).

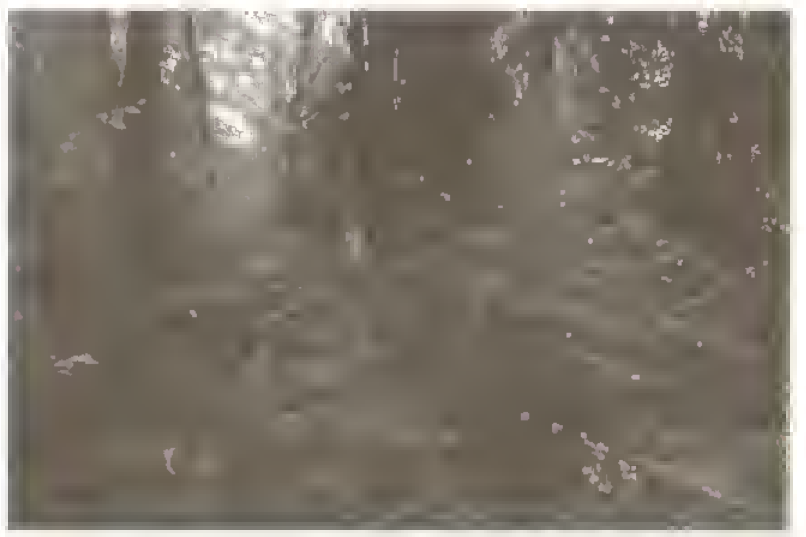
The measures taken for the protection of these Protected Nature Monuments are similar to those applying for the core of the National Parks.

Our country has designated 38 Protected Nature Monuments.

NATURAL RESERVES

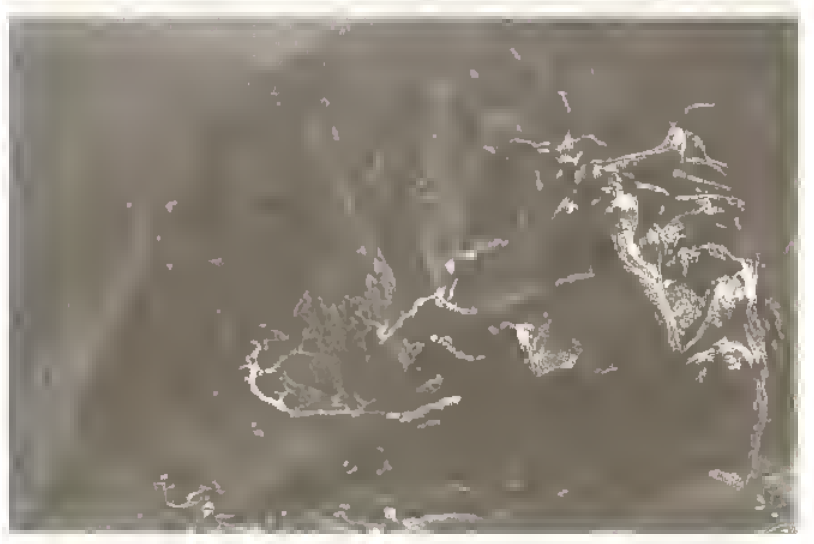
Apart from the above categories of forests that are interesting for forest recreation and are covered by the Greek legislation, there are some others at an international level that are interesting mostly from a scientific point of view.

One category is the Natural Reserves for which no relevant protection legislation exists yet (see Recreational Forests).



A natural reserve is a small or large area where:

1) One or several ecosystems are not materially altered by human exploitation and occupation. The vegetational and animal species, geomorphic formations and biotopes of a particular scientific interest.
2) The national competent authorities have undertaken initiatives to prevent and reduce their exploitation and occupation thus ensuring the effective conservation of their ecological and geomorphologic characteristics.
3) Visitors are allowed only upon a special license granted exclusively for educational purposes.



WILDERNESS AREA

Another category of forests that does not fall under the existing forest legislation is the **wilderness area,** which is a relatively large area where:

1) The various ecosystems are left in their natural dynamic evolution under the complete domination of every type of environmental factor (biotic or abiotic).
2) The competent authorities have taken all the necessary measures to protect it from any rational or intentional human intervention, even if it aims at supporting and speeding up its natural development.
3) Visitors are allowed only for cultural, educational and scientific purposes and for mental uplift or regeneration.

The differences between the wilderness areas and the natural reserves are:

a) The wilderness areas are larger than the natural reserves.

b) Their importance and interest is not only scientific.

c) Entrance is allowed to non-scientists for some types of recreation.

WETLANDS

Many wooded lands are dominated by water. Water determines the existence of the flora and fauna species.

The high diversity of the environment makes these areas particularly interesting in terms of recreation, education, scientific study and research, ecological balance etc.

In our country, there are wetlands at the river estuaries and in riparian areas e.g. Evros, Nestos, Axios, Messologgi lagoon, Prespes etc.

The term National Wetland designates a relatively flat and large area where:

1) The areas and shallow ecosystems that are not materially altered by human exploitation and occupation and where water predominance is a decisive biological factor and the plant and animal species are of particular scientific and educational interest adding high aesthetic value to the natural landscape and contributing to the ecological balance of the area.

2) The competent authorities have expressed the will to take all the necessary measures to protect and conserve the area's ecological and aesthetic attributes and ensure its adequate development.

3) Visitors are allowed under special conditions and strict rules for recreational, scientific and educational purposes.

4 RECREATION FACILITIES

The recreational activity with the lowest impact on the forest environment is walking through the development of a network of trails and pathways throughout the recreational forest area.

The trails and pathways allow the visitors to observe the forest beauty and to do some walking. They also link the various facilities and control the human flow in the forest thus contributing to its conservation and management.

Sometimes, creating a trail is sufficient for turning an area into a recreational forest. Therefore, trails and pathways are considered as the most significant 'infrastructure' in the recreational forest and need good planning.

The difference between trails and pathways is that pathways are usually narrow and simple and they are used less and usually aim at making access to some recreational facilities easier or opening a forest to the public.

During the study and the trails construction, all the above principles must be taken into account in order to satisfy the visitors' needs and ensure the forest conservation.

Some relevant instructions concern:

- The trail axis (itinerary),
- The trail attributes (inclination, carriage width, additional activities and recreational facilities)
- Their arrangement and conservation.

4.1 RECREATION FACILITIES: ENJOYING NATURE AND ENVIRONMENTAL EDUCATION

The trails that are developed in a forest allow visitors to enjoy nature and the landscape.

As a result, trails should cover a large part of the forest and cross various micro-environments to allow visitors to admire the forest beauties and attributes and enjoy various types of landscape along the way (e.g. typical forms, panoramic landscape, focal landscape, detail landscape, ephemeral/transient landscape etc.).

It is necessary to create "view points" for the panoramic landscapes that are visible from specific spots allowing visitors to make a break, rest and enjoy the view.

The "view points" may be part of the recreation facilities in a broader forest recreation area and connected to the main network of trails or auxiliary short pathways. Yet they may be cut off from the network and accessible only by car.

Anyway, to meet the visitors' needs, the "view points" should offer:

a) large parking lots allowing a large number of vehicles to get as close as possible

b) the trail linking the parking place to the "view points" square should be comfortable, short and safe

c) large, comfortable and well-arranged platform facilitated with all the necessary facilities to offer the best possible view to the visitors.

The platform that is usually congested during peak hours should be large enough to allow visitors to move around easily.

The facilities of the "view points" may include stone or wooden seats, small garbage bins, shelters and, possibly (in wetlands or high dense vegetation areas) special observatories and a map or plan on a special base (podium).

4.2 PICNIC - RESTING

Apart from the above mentioned activities and facilities, it is clear that visitors often look for well-organized and equipped accommodation places for a comfortable stay in a pleasant environment together with their family or friends. Such places also give them the possibility to enjoy a meal in nature in comfort and safety.

When possible, it is necessary to create playgrounds, as described in the next section.

The choice of the spots that will be used as picnic areas must be done very carefully in order to satisfy the visitors and forest's needs in compliance with the aforesaid sections.

Every picnic area should be equipped with special constructions such as:

a) Tables with special seats (benches),

b) litter bins,

c) running water for any use,

d) toilets,

e) shelters or pavillions.

If necessary, a parking lot must be built close to the picnic area.

In some cases, barbecue pits are built provided that food preparation is not dangerous for the forest and visitors use this facility properly without jeopardizing the forest safety.

4.3 GAMES AND HOBBIES

Playing in a natural environment is another activity that pleases children and parents since it allows them to exercise and relax.

As seen above, creating facilities for organized sports activities requires caution and specialized knowledge.

A simple facility that is suitable for forest and goes hand in hand with other activities and forest

recreation facilities is the kids **"playground"** and the **"free play areas"**, where visitors can play various simple games (rackets, volley-ball, football etc.).

The playgrounds usually include wooden constructions such as: seesaws, balance beams, pyramids, climbers, swings, sliders, sandboxes, little wooden houses etc. There are many plans that may inspire those in charge of planning play areas.

The "open play areas" are mostly flat areas of 0,1-0,2 *ha* that are selected among the existing open areas or are specially created for this purpose.

These are construction- and vegetation-free areas that are being cleaned and, if necessary flat-

tened in order to allow the visitors to play simple outdoor games.

Some of the trees (0,2-0,3 *ha*) may be kept in the open area as shelters or game facility.

Both open play areas and playgrounds are often delineated by means of elegant low wooden fences. It is also recommended to place garbage bins and benches (with or without back) allowing the visitors to rest and watch their children play.

As for the hobbies, they include photography, natural history study, wild life sample collection, rock collection, bird watching etc.

Usually, apart from good signing and information and, in some cases, special observatories, hobbies do not require particular constructions.

In addition, it is possible to pursue **special activities** (**ex. climbing**) in forest recreation areas when there are areas suitable for such activities.

In such cases, the facilities must be as integrated as possible into the landscape.

4.4 OPERATIONAL ORGANIZATION OF THE RECREATION SITES

To ensure an integrated organization of a forest for recreation purposes, a proper development and effective conservation/operation are necessary taking into account the users needs.

By doing so, it will be possible to avoid omissions and problems that may cause their discontent and, by extension, intentional pollution and damaging actions.

Apart from the above works referring to the development of outdoor recreational activities, the forest also needs some additional special constructions or works in order to:

a) define its character as recreational forest,

b) facilitate its operation,

c) improve its protection conditions.

These facilities are mentioned below and refer to the following categories that will shall be taken into account when creating forest recreational areas:

1. Forest accessibility
2. Infrastructure works (water supply-sewage system)
3. Parking lots
4. Forest entrance-exit
5. Visitors information points
6. Installation of information signs
7. Installation of a guardhouse
8. Forest protection works (fences, fire protection equipment)
9. Publication of an operation guide, information brochure and designation of a forest-park management body.

SURFACE WATER

LAKE ECOLOGY

OVERVIEW

Since the past, lakes have had a leading part in people's life affecting the development of their areas and activities.

Apart from their natural beauty, particular geomorphology and rich flora and fauna, lakes are also important because they constitute water resources of high value for man. **Lake is a small or large inland body of open freshwater, saline or salt water occupying a hollow in the earth's surface and is cut off from the sea.**

Lakes are divided into two large categories:

Natural lakes: Lakes that were created from various geological processes such as the retreat of glaciers, volcano eruption and tectonic uplift, soil and rock erosion and rivers effect.

Artificial lakes: Also called reservoirs: they are formed by flooding land behind a dam or by human excavation. They vary in size and form and vary from small water reservoirs that were created following a dam construction to large lakes that were formed by dams constructed in large rivers.

ORIGIN-BASED CLASSIFICATION

Tectonic (or Rift) lakes: Basins formed by movement of the Earth's crust. Most of the tectonic lakes were formed by one single fault or multiple adjacent faults. The tectonic-origin lake

basin was formed by a soil sinking due to a fault movement or the immersion of a wider area that is located between two adjacent faults. The largest and deepest lakes such as Lake Baikal in Siberia, the big lakes of East Africa, i.e. Malawi Lake, Lake Tanganyika, Lake Edward, Lake Albert and Turkana Lake as well as the Dead Sea are of tectonic origin. A second type of tectonic-origin lakes were created by the uplift of sea floor parts. Such lakes are Lake Victoria, Lake Africa, Lake Tikitaka high in the Andes.

Volcanic (or Crater lakes): The most well-known crater lakes are those that form in the calderas or craters of inactive volcanoes such as Crater Lake in Oregon which is 10 km across while its deepest point has been measured at 600m deep, Crater Butte Lake in California and the shallow lake Mahega in Uganda with alkaline water and a few centimeters transparent water.

Glacial lakes: Most of the world's lake catchment areas were formed during the Pleistocene when a large part of the Earth was covered by ice. This period created the conditions for the formation of the glacial lakes that are usually longitudinal and their initial formation is due to the glaciers passage through the old river valley that was dug and widened while its lowest part was filled mostly with sediments and rocks (Morenes). The fjords that are very deep and have steep coasts are also of glacial origin. These basins were covered with water when the ice retreated thus forming the large lakes of Northern America and Northern Europe.

Turlough lakes: A type of lake found only in limestone areas where karstic phenomena are observed (hollows, openings, gulfs due to limestone erosion). Limestones or dolomite rocks can be dissolved away by surface or groundwater which, then feeds these lakes. Such lakes that are covered to a great extent by limestones are Prespes lake, Vegoritida lake, Kastoria lake, Ioannina lake and the dried lake of Kopaida.

Shoreline lakes: Their formation is generally a result of the sea stream effect to the coast that transfer sand and deposit it in the river estuaries thus creating a blocking dam. If the sea is completely cut off, a shoreline lake is created such as the Agoulinitsa lake. If the sea is not completely cut off, it communicates with the lake creating a lagoon such as the Messologgi lagoon, the Porto Lagos lagoon in Xanthi etc.

MAIN FEATURES

Size and form The lakes vary in size and form. Their origin determines their dimension and features. The size refers to the total surface they cover and their deepness. The lake deepness

does not depend on the surface covered by them but mostly on their origin. Rift, crater and turlough lakes are usually very deep while the alluvial or Aeolian ones are generally shallow. With regard to the form, they are divided into longitudinal, circular, meander or irregular lakes.

Lake level This is the level of the lake surface compared to the sea level. The lake level changes in the course of time. This occurs mostly to lakes that are karstic and shallow during the dry periods. The change in the lake level is usually due to climate change, water inflow and outflow and feeding of the lake with sediments.

Relation of the lake surface to the drainage basin. A lake that is relatively small in proportion to its drainage basin is more likely to be filled with sediments from waterstreams, to be affected by their nutrients or to be subject to eutrophication than a large lake with a small catchment area.

Lake plant growth: It depends on the lake's richness of nutrients (i.e. the substances that are necessary for the plant growth) and determines the food condition of the lake. As a result, any extreme level of nutrients (high or low) reduces the aquatic life significantly. A high level of nutrients equals excessive increase in the phytoplankton and the other aquatic flora. On the contrary, a low productivity reduces the aquatic life. Lakes may be distinguished based on their productivity: oligotrophic are the lakes with low biotic productivity, mesotrophic are the lakes with medium productivity, eutrophic are those with high biotic productivity and hypertrophic are those with excessive productivity. The passage from oligotrophic to eutrophic is a natural process that lasts thousands or millions of years because nutrients from the catchment area inflow very slowly in the lake. However, human interventions in the catchment area may trigger radical change in the productivity level in a short period of time. It must be pointed out that any increase in the nutrient concentration of a lake is desired to some extent since it implies increase in the fish catches. Yet stabilizing the lake's eutrophic or hypertrophic condition is not recommended because it implies creating anoxic conditions in the deepest layers, which will alter the composition of the lake biosocieties.

Lake water balance: The characteristics of the catchment area affect the lake water balance significantly. The water that inflows in the lake through direct rainfall, underground sources and surface torrent and stream in adjunction to the water that outflows the lake either through surface

outflow, evaporation, plant transpiration and underground leakages determine the concentration of nutrients, sediments and other substances, possibly pollutants in the lake and the existence of the organisms living in it.

Lake water time renewal: The time required for a full renewal of the lake water is a particularly significant factor. For instance, if the water volume of a lake is relatively low and the run off is big, water spends less time in a lake and, as a result, the nutrients that are likely to cause explosion of phytoplankton will be soon removed by the water body. On the contrary, the more time needed for the water renewal, the better the temperature and nutrient conditions for the development of phytoplankton.

Lake water temperature: The lake temperature depends on a number of factors such as geographical width, altitude, local climate conditions, sunlight etc. There are three layers of drastically changing temperature relative to depth. In the surface layer (12 m) temperature varies and is affected by the atmosphere. Below this layer, the temperature drops very rapidly and gradually (1 ^{0}C/m). In the third layer, water temperature remains stable. In most lakes, temperature seasonal differences cause water inversion, that is mixing up the surface water with the deeper layers and, thus, the surface water is shrunk and the water in the bottom goes up to the upper water.

This is a significant phenomenon since the nutrients that are usually deposited in the bottom enrich the higher layers and can be used by the photosynthetic organisms (phytoplankton, higher aquatic plants).

Lake chemical composition. Depending on their richness of salts, lakes are categorized in freshwater, saline or salt water lakes. Depending on their chemical composition they are divided into calcium, chloride, magnesium, sulphuric etc.

Lake categories	Salinity (%)
Freshwater lakes	0,03 – 0,1
Saline lakes	0,1 – 2,47
Salt water lakes	> 2,47

Climate and soil: The climate and soil conditions of the catchment area of a lake affect the emergence of eutrophication. The lakes that are located in high rainfall areas with erodable and nutrient-rich soil are more likely to present eutrophism and expansion of aquatic plants, than those found in dry climates and arid soils.

Riparian wetlands: They (water meadows, aquatic forests etc.) have a leading part in the lakes ecology. Both water meadows and riparian aquatic forests depend on the lake and are a suitable

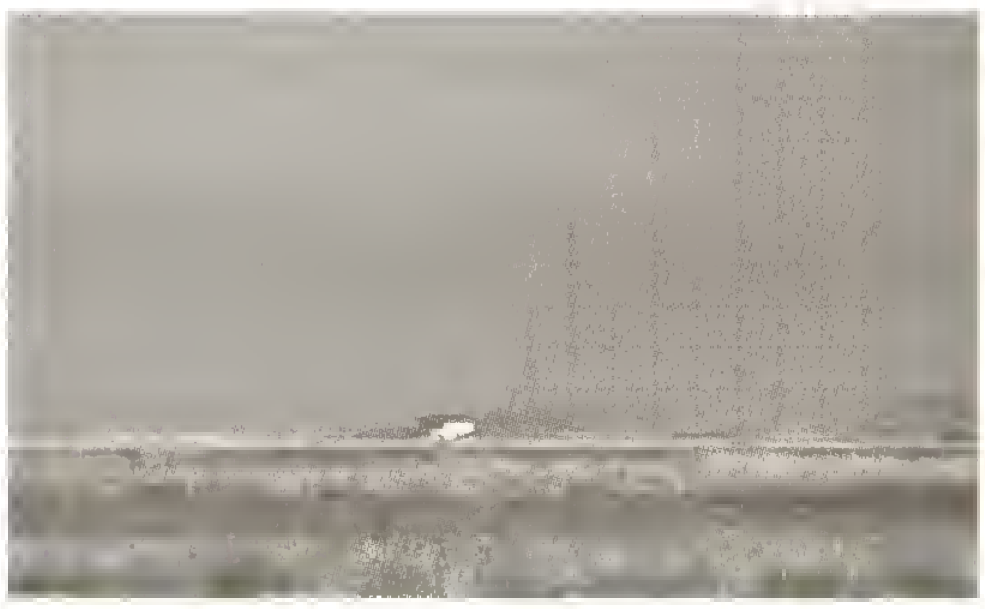
biotope for preserving biodiversity and developing flora and fauna. Also, they retain the various pollutants before they reach the lake (mostly non point pollution due to excessive use of fertilizers in crops and is transferred by the run off water) improving the lake water quality and contributing in the lake's sustainability.

WATER QUALITY

Water quality determines the function of the lake ecosystem. As a result, any material, energy or microorganism may cause its downgrading. Its evaluation may be carried out by means of measuring some basic physical and chemical parameters that are presented below.

Sunlight: Solar radiation is the most significant factor because it is the main source of heat and is associated with the photosynthesis that is used for producing organic matter. Water, water dissolved substances and suspended particles refract and absorb light reducing the water clarity. The light depth or transparency is measured by using a Secchi disc.

Color: The water color is determined by the depth which light can reach, the particles in suspen-



sion from dissolved inorganic or organic substances, the type of plankton organisms, the sediment color and the geological substrate of the area. All these factors diffuse and absorb light and are responsible for the greenish, blue or dark brown color of the water.

Smell: Natural or human causes are responsible for the smell of the lake water. The water smell in a eutrophic lake is due to the breaking down of organic matter. The chlorium-based waste management is responsible for a smell of chlorium or chlorophenol.

Temperature: It affects oxygen and other agents' dissolvability, the metabolism of aquatic organisms, the breaking down of organic substances and is responsible for the thermoclines and the water inversion.

Electrical conductivity: It is the water's ability to conduct an electric current and depends on the concentration of ionized chemicals in water, their quantity, flexibility, strength and temperature. Any waste and pollutant inflowing in the lake increases the water electrical conductivity.

Dissolved oxygen: The concentration of dissolved oxygen in water is related to the development of most forms of life. Lake enrichment with oxygen is achieved through the diffusion of atmospheric oxygen in the lake water and through photosynthetic production. Oxygen solvability in water depends on the temperature, atmospheric pressure, waving, concentration of inorganic salts and organic substances, microorganisms etc. A high volume of nutrients inflow in the lake due to natural or human activities causes a decrease or lack of oxygen.

Biochemical Oxygen Demand: The amount of oxygen required by aerobic microorganisms to decompose the organic matter in a sample of water is called B.O.D.

pH: The sum of biochemical coumpounds in the cells are carried out in a neutral pH. Water active acidity depends on the temperature, salinity, CO_2 and oxygen concentration in water, metabolism of aquatic organisms (photosynthesis, breathing), chemical decomposition of organic substances and effect from external factors.

Nutrients: The main nutrients of a lake plant organisms are the nitrates, nitrite, ammonia and phosphates that determine the food status of a lake, which is indicative of the lake condition (oligotrophic, mesotrophic, eutrophic).

Toxic substances: Natural or composite substances (lead, mercury, fluoride, cadmium, radionuclide, pesticides etc.) may have a toxic effect to the organisms that uptake them. An increase in the concentration of a toxic substance in a biological organism over time is called bioaccumulation.

LAKE MAIN THREATS

Increased nutrient availability: It leads to an increase in the phytoplankton and other plant forms thus reducing the oxygen that is available to fish and other organisms.

Organic waste: The decomposition of organic material may cause water oxygen insufficiency, which impedes the survival of fish and other aquatic organisms.

Sediment increase: Inflow of sediments from the catchment area decreases the lake depth, destroys the environment of some plants and animals and, under some conditions, chokes up the fish gills causing them asphyxia and killing their eggs.

Heavy metals and organic chemical compounds contaminate fish and shell-fish.

Steep fluctuations of lake level due to the use of the lake for power supply, irrigation purposes and other uses. The steep fluctuations of the water level affect adversely the wild life and the aquatic plants.

Sources of pollution: A wide range of primary sources of pollution are often found in the catchment area. Such sources are agricultural cultivations that cause nitrogen, phosphorus, sediment, pesticide and organic materials inflow in the lake. Also, leaching from urban areas include fuel, metal, bacteria, nutrient waste etc. that are transferred through sewage systems or the rain water drainage networks in the lake.

Other lake contaminants are leakages of the sewage systems (sewers, pits) that pollute or contaminate lakes because of the nutrients, bacteria and other waste that end in the lakes. Any damage of the riparian vegetation due to construction works in the area affects lakes and downgrades their water quality. Very often, atmospheric precipitation contains pollutants that are transferred in the soil through the rain and threaten the lakes found in heavy industry areas. Finally, urbanizing rural and forest lands results in the construction of "hard" surfaces, such as roads, parking lots, shelters and pavements, which, in turn, causes run off speed, erosion in

the river banks, water turbidity and degradation of the wild life environment.

LAKE MANAGEMENT

The lake ecosystem is particularly vulnerable and requires an integrated monitoring plan with long-term recurrent samplings in various positions. The following measurements are necessary:

Lakes

1. Water temperature
2. Water color- odor
3. Turbidity
4. pH
5. Conductivity
6. PO4-3
7. NO3-1

Streams that join lakes

1. The same measurements as in the lake water body.
2. Sediment assessment (quality and quantity).
3. Flow assessment through the flow speed measurement.

Biological parameters

1. Reference to the most commonly observed macro-invertebrates.
2. Reference to the fish species (in cooperation with the fishermen of the area).
3. Assessing the pisciculture.
4. Observing the bird species at every season and assessing the size of their populations.
5. Observing the riparian vegetation and recording the main species.
6. Assessing the food condition of a lake.

Catchment area

1. Surface, average level, lake altitude.
2. Plant coverage (predominant species – coverage rage) and reference to the human interventions.
3. Land use and crops.
4. Catchment area rock and geological formation permeability.
5. Weather conditions in the catchment area.

TORRENTIAL PHENOMENA INVOLVING SEDIMENT PRODUCTION AND TRANSPORT

GENERAL

Rainwater, as it flows from drainage basins and along streambeds, dislodges solid material (**sediment**) and carries it downstream, either depositing it at low-lying areas (planes and semi-planes) or releasing it into receptor water bodies (rivers, lakes, the sea). Sediment can sometimes incorporate tree trunks, cants, stumps and branches. When streams cross towns and villages, their beds receive foreign materials from refuse, fills, quarries, technical works and even sewage.

Sediment transport is a basic function of torrential streams. It can be broken down into three stages:

- **production** of sediment as the torrent forms in drainage basins up in the mountains.
- **transportation** of sediments through the hydroraphic network of streams, and
- **depositing** of materials at the low-lying areas of the torrent's course.

The direct effect of climatic conditions on the geological substrate of torrents, in combination with other, indirect, effects results in the following **sediment-producing torrential phenomena**:

- erosion
- rock disintegration
- landfalls
- landslides



Anthropogenic effects also play a role by accumulating significant quantities of autochthonous or heterochthonous material in the torrent streambed.

The surfaces that form in the course of the torrent by the dislodging action of the above effects are **sediment production sites**.

SEDIMENT-PRODUCING TORRENTIAL EFFECTS

EROSION

Erosion is the wearing away of the land surface by wind, flowing water or other geological agents. It can be a natural process caused by weather events but it is often augmented by anthropogenic practices (logging, forest fires etc.). The shape of raindrops impacting the soil surface as well as the intensity of rainfall directly correlate with the extent of erosion. Also, the extent of erosion depends on the properties of the geological substrate such as its type, structure of its constituents, its porosity, water permeability, texture etc. Therefore, sedimentary rocks are particularly susceptible to erosion contrary to igneous and metamorphic rocks that are more resistant. The

bigger the inclination, the greater the impact of erosion processes in the drainage basin. Finally, the existence of plant cover, woodland in particular, protects the geological substrate from erosion and root systems help stabilize it. There are six main types of erosion:

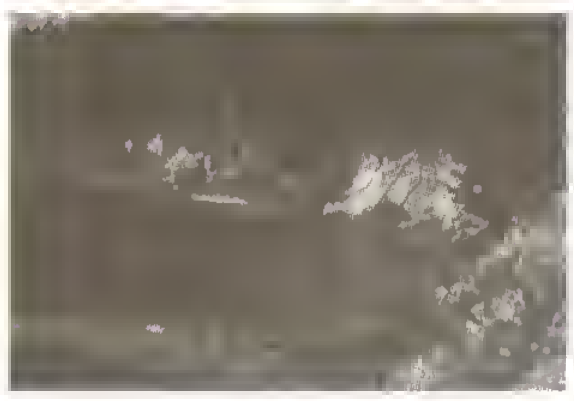
Sheet erosion: gradual removal of fairly uniform, thin layers of earth-surface material by runoff.

Rill erosion: a form of erosion involving formation of numerous small channels by running water (up to 1m deep), which may be smoothed out by cultivation.

Gully erosion: erosion creating relatively deep trenches (> 1m) along the water's flow, too large to be removed by normal tillage operations.

Ravine erosion: gully erosion where trenches of much larger size are formed (40m – 100m). Most often seen in the main streambed, particularly at its lower part.

Lateral erosion: Erosion of stream banks caused by the flowing water of a stream cutting into the foot of the bank and dislodging material which is then carried downstream.



Undermining erosion: vertical erosion causing deepening of the natural bed of a watercourse due to the hydraulic power of flowing water impacting the bed at an angle. This type of erosion is seen at the base of natural waterfalls, at the foot of embankments and downstream from reinforced streambeds.

Distinguishing these types of erosion is helpful not only for study purposes but also for selecting the best-suited management approach. However, in nature, these erosion types are rarely seen independent from one another; they generally appear as **complex** erosion mechanisms encompassing many types of erosion to varying degrees.

WEATHERING

The effect of the environment's physical and chemical energy on the surface of the geological substrate, combined with the action of various organisms (plants in particular), cause rock loosening, alteration of rock composition and rock fragmentation. This phenomenon is called **weathering**. Disintegration can be physical, chemical and biological.

Physical or mechanical disintegration is mostly due to the action of heat and water. Successive changes in temperature cause rock volume fluctuations. This results in the loosening of rock cohesion and the appearance of fissures and cracks, ultimately leading to the fragmentation of rocky masses. The hydraulic force applied by water in the rock's cracks acts similarly to water pressure in

rock pores. Water trapped inside cracks in rock mass often results in the development of great hydraulic loads, capable of causing fractures even in adjacent rocks. Ice also has a strong disintegrating effect on rocks. As water freezes inside rock pores, water volume increases. The intense pressure thus exerted on pore walls loosens the rock mass and results in its fragmentation.

Chemical disintegration leads to radical changes in the chemical composition of rocks. It is caused by carbon dioxide, which acts on acid chemical substances, as well as oxygen and water, which have a hydrolytic action.

Finally, **biological** disintegration is caused by the action of various organisms. Plants extend their root system deep into rock fissures and cracks, expanding them and fragmenting rock mass, thus allowing water to penetrate and mechanical erosion to take place. Also, decaying roots produce carbon dioxide and hydrogen sulphide that are taken up by circulating water increasing its dissolving power. The intensity of rock disintegration depends mainly on climate, altitude, mineral composition, relief, schistosity, chemical composition of rocks, declivity exposure and vegetation presence and type.

In areas with frequent and abundant rainfall and abrupt temperature changes, especially around the melting and freezing point of water, rocks are subject to intense disintegration. Lime, especially tabular, and shale present high levels of disintegration. Other rocks disintegrate at a slower rate. Some more examples of rocks susceptible to disintegration include conglomerates and sandstones, depending on their binding material and the nature of the pebbles and grains they are composed of. Basalt, diabase and, to a smaller extent, granite are generally resistant to disintegration, while gneiss disintegrates more readily.

ROCKFALLING

A rockfalling occurs when rocky or earthy masses become dislodged due to various causes and fragmented in materials of various sizes, which then slide down declivities independently from one another or fall and collect at lower sites where they are deposited according to size (sorting). It follows that landfalls go hand in hand with disintegration, since it is the process of disintegration that provides the falling materials.

Said materials come mainly from rock disintegration taking place in areas above woodland limits. In these cases, disintegration is the process producing the materials and landfall is the mechanism that transports them downhill. Other processes may result in the production of landfall materials, such as the undercutting of stream banks, the opening of roads, construction of various technical works etc. Landfalls are particularly intense in mountain drainage basins with tabular lime, as well as in streambeds with sedimentary rocks. Lack of stability in declivities, earthquakes and other causes of geological mass vibration may also contribute to landfalls.

Depending on the size and quantity of falling material,

the following types of landfalls may be distinguished:

Sandfalls: Falling material is made up of small rock particles (sand-sized) from rocky, heavily inclined declivities or from sedimentary rock slopes and the landfall itself occurs through the action of gravity. Falling material collects at the foot of the declivity or slope forming small cones.

Stonefalls/rockfalls: Falling material is made up of stones or rocks, a few centimetres up to one metre in diameter, usually tabulary, which derive from the fragmentation of rocky slopes or declivities. Their deposition takes place by sorting at the foot of the slopes.

Mountainfalls: A sudden fall of very large rock masses, thousands of cubic meters in volume. They begin by moving as a cohesive mass or by sliding. In the end, they simply fall. This movement is seen in steep declivities and is usually very rapid.

Mixed types: Landfalls combining the above types.

LANDSLIDES

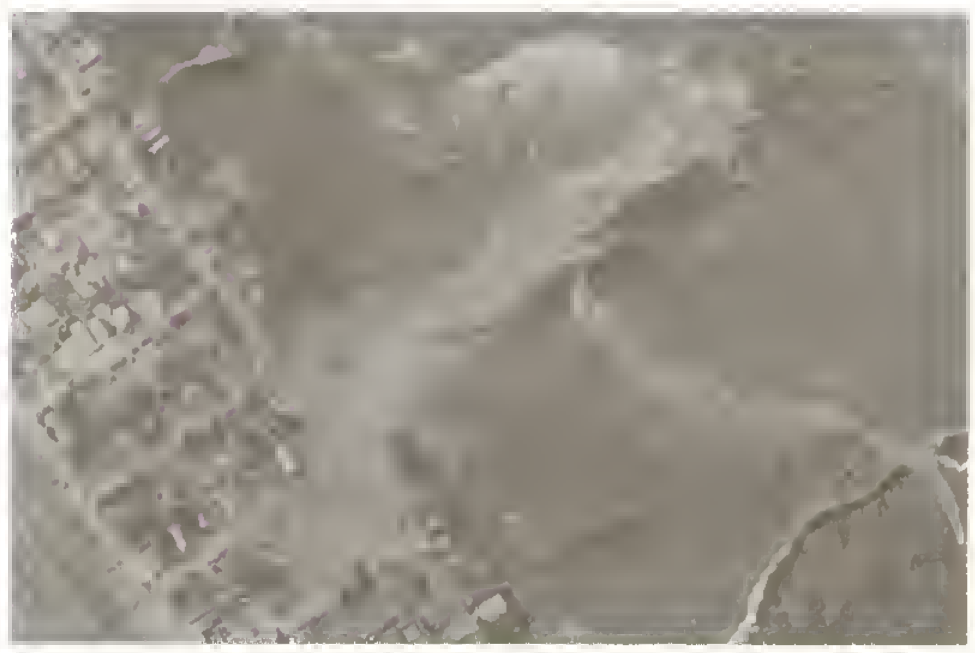
Landslides are defined as the downslope movement, under gravity, of masses of **saturated** soil and rock material. The movement follows the direction of maximum inclination. Landslide materials are deposited at lower, less steep areas, **without sorting**. Consequently, sorting is what differentiates landfalls from landslides.

As a rule, geological masses slide along a sliding surface more or less well-defined, which is referred to as "sliding plane", although the surface itself may be convex (**circumferential landslide).** Sometimes, the transition from the sliding to the immobile part of the mass is progressive without the creation of a sliding plane (soil creeps).

The main factors affecting the mechanism behind landslides are the following:

1. precipitation: the height, intensity and duration of precipitation significantly affect the intensity and frequency of landslides. Repeated rainfalls of long duration on bare mountain drainage basins, even if intensity is low, cause many landslides due to subsoil saturation.

2. groundwater: groundwater quantities are affected by fluctuations in precipitation. Because of changes in the flow and pressure of groundwater due to precipitation fluctuations, forces are exerted causing an increase in the gyroscopic moment of geological masses. Any obstruction (artificial or natural) in the out-



flow positions (springs) can trigger a landslide.

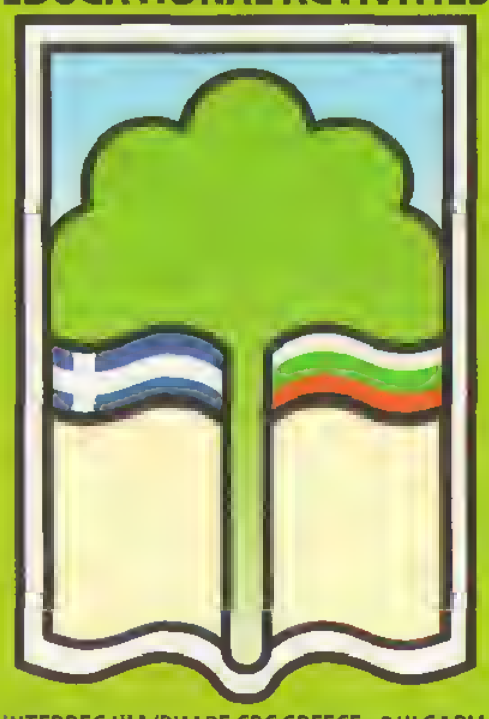
3. inclination of geological layers: An increase in the inclination of declivities and slopes favours landslides. The bigger the inclination, the easier it is for the masses to slide, because the inclination angle of their layers is one of the parameters involved.

4. granulometry: the granulometric composition of geological layers affects the weight and hydrological properties of geological masses, which in turn determine the friction coefficient and consequently their sliding potential. For example, geological layers of high permeability, such as conglomerates without argil, moraines, coarse sand layers etc. do not generally slide easily because they do not retain water, in other words, they do not become saturated. The higher the permeability of geological layers, the greater their sliding tendency because the water being retained in the pores exerts significant pressure. Geological layers with >0.2mm granulometry are relatively stable. If granulometry is between 0.2 to 0.002 mm sliding tendency is considerable.

5. slope undercutting: Flowing water undercuts the foot of the slopes along the streambed, destabilising them. If declivities become saturated enough to significantly decrease friction of their geological masses, slopes will slide or collapse, feeding large sediment quantities into streams.

6. anthropogenic influences: these may cause changes to the outer layers of declivities and shifts in the geological masses resulting in slides in mountain drainage basins; they include road construction, railway bridges or tunnels, earthworks on slopes, irrigation installations etc.

DEVELOPMENT OF JOINT EDUCATIONAL ACTIVITIES



INTERREG IIIA/PHARE CBC GREECE - BULGARIA

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